VOL. IX NO. 5

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

NOVEMBER 1921

SOCIETY OF AUTOMOTIVE ENGINEERS INC.
29 WEST 39TH STREET NEW YORK

The American Bronze Corporation announces that it is now casting and machining bushings of special specification bronzes

THIS radical change from our basic policy of manufacturing but one alloy has been brought about by the research work of our Technical Bureau who have found that there are many places where a high quality specification bronze will give satisfactory service and where the quality of Non-Gran is higher and more expensive than the service conditions demand.

We bring to the production of these bushings the years of foundry and machine experience which have been devoted to the production of Non-Gran, the highest grade of bearing metal.

It is reasonable to assume that the same knowledge and experience which have made Non-Gran an unquestioned standard of quality may also be depended upon to produce specification bronzes of distinct superiority.

The specification bushings will be manufactured in an entirely separate plant which will be equipped similarly to our Non-Gran plant and full advantage will be taken of the improved methods of foundry and machine practice which we have developed.

All of our specification bronzes will be made of virgin ingots and under no circumstances will we use specification ingots, which always contain more or less scrap.

* * *

THE extraordinary wear-resisting qualities of Non-Gran result from its physical properties rather than its chemical composition.

The chemical composition of Non-Gran approximates ordinary bronze but microscopic examination shows it to have a more dense and homogeneous structure than ordinary bronzes.

That is what gives Non-Gran its remarkable resistance to wear—as its particles are not torn away by frictional drag.

All Non-Gran castings are marked Non-Gran.

* * *

OUR Technical Bureau is fully manned and equipped to carry on experiments and tests for the purpose of assisting manufacturers in the proper use of plain bearings.

Manufacturers are urged to submit their bearing problems to us for careful impartial consideration.

AMERICAN BRONZE CORPORATION

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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. IX November, 1921 No. 5

Winter Meetings

PLANS for the winter meetings of the Society are now well advanced and it is possible to announce many details of the programs at this early date. The Annual Meeting will be held at New York City, Jan. 10-13; the Chicago Meeting will be convened, Feb. 1, during Show Week, and the Annual Tractor Meeting is scheduled for Minneapolis, Feb. 8, during the week of the National Tractor Show. The Meetings Committee also has plans under consideration for other national meetings but dates have not been decided upon devnitely for them.

THE ANNUAL MEETING

The technical sessions during the Annual Meeting will all be held in the Engineering Societies Building, 29 West 39th Street, New York City, where the headquarters of the Society are located.

Standards Committee Report

The Standards Committee will hold its meetings Tuesday morning and afternoon, Jan. 10. A large number of the Divisions of the Standards Committee have been very active during the summer and fall preparing reports on many subjects for submission at these meetings. One of the most important reports will be that of the Iron and Steel Division. The work of completely revising, and extending, the well known S.A.E. Steel Specifications has been completed. The report of the Division is the result of months of study and many sessions of its members.

Aeronautic Session

An Aeronautic Engineering Session will be held Tuesday evening, when a paper on Air-Cooled Engines will be presented by Charles Lawrance, a member of the Society who has specialized on this type of powerplant for airplane use. Other papers are contemplated for this meeting but have not yet been selected.

Business and Research

The Business Meeting, to be held Wednesday morning, will differ somewhat from those of previous years. It is intended to have the formal reports of the officers preprinted in full and circulated so that only very brief oral presentation of them will be necessary in the meeting itself. The time saved in this way will be devoted to careful consideration of the organization and future plans of the Society's new Research Department. Dr. H. C. Dickinson, the manager of the department, and H. M. Crane, chairman of the Research Committee, will lead the discussion.

Bodies, Lubrication and Trucks

Three simultaneous sessions will be on Wednesday afternoon, on Body Engineering, Lubrication, and Commercial Vehicles. The Body Engineering Session will be opened with a paper on Harmony in Car Upholstery by R. F. Quaintance, who has been identified with the manufacture of upholstering materials for a number of years. This will be followed by a paper on Body Seating-Dimensions, by George E. Goddard. L. V. Pulsifer, a chemist specializing in the paint and varnish field, will read a paper on the Manufacture and Proper Application of Automobile Paints and Varnishes. The so-called California Top, which has become very popular throughout the entire Country in recent months, will be discussed by Paul W. Steinbeck, a body engineer of long experience.

The Lubrication Session will include three papers by men who have made intensive study of problems in this field; Neil MacCoull of the Texas Co.; W. H. Herschel of the Bureau of Standards and Robert E. Wilson of the Massachusetts Institute of Technology.

Only one paper can be definitely announced now for the Commercial Vehicle Session. This will be presented by M. C. Horine, the subject being the Economics of Truck Transportation. Other features of this session will be announced in due course.

Ricardo to Present Paper

A matter of unusual interest is the announcement that Harry Ricardo, of Great Britain, has accepted the invitation of the Society to visit this Country and address the members at the time of the Annual Meeting. The conspicuous research studies of Mr. Ricardo in the field of automotive engineering are widely known. The quantitative results of his fuel investigations and his work on combustion-chamber forms, turbulence, stratification and supercharging have been published extensively. His study of mechanical losses in internal-combustion engines led to the development by him of novel and interesting piston designs.

Mr. Ricardo's paper at the Annual Meeting will be based upon his research work and contains much valuable automotive engineering data. The entire morning session on Thursday will be devoted to the presentation and discussion of the Ricardo paper. This arrangement has

been made because it is expected that the members will want to discuss the paper very thoroughly after its presentation at this session.

Fuel and Materials Sessions

There will be two simultaneous sessions on Thursday afternoon, one on Fuel and Engines and the other on Automotive Materials. In the former Thomas Midgley, Jr., and W. K. Gilkie will give a joint paper describing a study they have made of combustion by the spectroscope. This will be followed with a paper by O. C. Berry on exhaust temperatures and evaporation of engine fuels. A method of measuring detonation or fuel knock will be the subject of a second joint paper submitted by T. A. Boyd and Thomas Midgley, Jr. It is expected that the Bureau of Standards also will cooperate in this meeting.

The Automotive Materials Session will assume the form of a symposium on the recent development of the metals entering into the construction of automotive vehicles, and will include several papers. Aluminum and its alloys will be treated by Zay Jeffries, malleable iron by Enrique Touceda and rolled forgings by G. R. Norton. It is planned to have additional papers on drop-forging practice and alloy steels. It is the purpose of this session to acquaint the members with the advances made in these materials that assure the accomplishment of lighter designs for vehicles without reducing the strength of the various parts appreciably.

Passenger Cars

On Friday morning there will be a Passenger-Car Session, the major part of which will be devoted to the discussion of brakes. J. Edward Schipper will present a paper that brings together many dimensional and descriptive data on brakes, and S. Von Ammon will describe the comprehensive tests of brake-linings that have been conducted at the Bureau of Standards. It is stated that the tests have established coefficients of friction applicable to brake design which can be accepted as accurate in view of the multiplicity of tests from which they were derived.

Carnival and Dinner

The Carnival of 1922 will be held at the Hotel Pennsylvania, Wednesday evening, Jan. 12. It is the one big family social event of Show Week and by past performance has become an established feature of the Annual Meeting. This year the responsibility for the success of the Carnival rests with B. G. Koether, and that fact alone will convince those acquainted with him that a good time will be had by all. The Annual Dinner will take place in the spacious ballroom of the Hotel Astor as in years past. The Dinner is the largest gathering of representative automotive men at the banquet table in the year. Men representing the production, distribution, engineering and financial groups will be seated there. C. F. Kettering will again serve in the capacity of toastmaster as a result of popular demand.

THE CHICAGO MEETING

The Society will hold a dinner on Wednesday of Automobile Show Week in Chicago. This falls on Feb. 1. The Hotel Drake has been selected as the place for this event. Morning and afternoon meetings also will be held on this same day and both of these will be concerned principally with problems of service, operation and maintenance. Appreciation of the need for concerted study of the service man's troubles is increasing constantly and it is the object of these meetings to encourage the further investigation of every means of reducing operating expense.

MINNEAPOLIS TRACTOR MEETING

The Tractor Show will be held this winter at Minneapolis and the Society has made arrangements for its 1922 Tractor and Farm Power Meeting in that city on Feb. 8, during the Show, inasmuch as a large percentage of the members engaged in this branch of the industry will be there at the time. A Farm Power Dinner will be given and at least two technical sessions held. It is anticipated that the Minneapolis Section members will take a very active part in the conduct of this meeting, since their interest lies largely in the farm power field.

BALL BEARINGS

THE steel balls manufactured by Rudge-Whitworth, Ltd., in all sizes up to ½-in. diameter are cold-headed from a special chrome alloy steel, and above ½-in. diameter are hot-forged from a similar material. Each ball rod is tested before and after use, the balls being etched, crushed and compressed after the grinding operation, so as to reveal the microstructure and any minute scratches incurred during polishing. Other samples are subjected to a running test, in which each ball is put under 10 times the guaranteed load. In a crushing test three balls are compressed in a line until the middle one breaks, thus indicating the toughness. The spherity is tested by subjecting the balls to various loads and measuring the flats microscopically. These balls are made in all sizes ranging from ⅛ to 3 in. in diameter.

The Hoffmann steel balls are guaranteed to be within 0.0001 in. of standard, both as regards size and spherity. The races are ground, and afterward highly finished, as it is obvious that the surface on which the balls are to run must be as highly finished and as accurate as the balls themselves; otherwise the skill and care involved in the turning out of a high-grade ball is practically useless. Eventually the races are inspected and gaged four times on all dimensions, this of course being exclusive of the gaging carried out by the operators during manufacture. These gaging operations are performed during assembly, after the whole of the machining processes have been completed. All these measurements, which naturally involve a high degree of accuracy, are based on standard end-measuring rods that are tested frequently at the National Physical Laboratory.

Hoffmann journal bearings are tested for outside diameter, bore of the inner race, width, face and track diameter of both races, and the radii of the corners of the outer and inner races. After assembly the bearings are checked for concentricity of face and outside diameter with the bore of the inner race. Simple thrust bearings are tested for outside and inside diameters, thickness, curvature and depth of ball-track, concentricity of ball-track with inside and outside diameters, and, further, each ring is carefully examined for warping or buckling.

Whatever friction exists in ball bearings remains practically constant even after years of hard wear. Provided the bearing is well made and correctly mounted, its efficiency will not deteriorate.

Though ball bearings need little care when once properly mounted, lubrication is very important, and the makers, as a rule, recommend a suitable oil or grease. It is naturally essential that the lubricant used should be entirely free from any impurities such as dust or other gritty substances; further, it should also be neutral, that is, free from alkali or acid.—*Engineering Production* (London).

Fuel Research Developments

By C. F. KETTERING[1]

ANNUAL MEETING PAPER *Illustrated with* CHARTS AND DIAGRAMS

TWO distinct problems are involved in fuel research work, multi-cylinder distribution and the chemical constitution of the fuel mixture after it enters an engine cylinder. In discussing elementary combustion, the author refers to the components of the energy of combustion as gravitational, kinetic and barometric, and elaborates his theme with the aid of diagrams and charts showing normal and abnormal combustion.

After emphasizing the necessity of theorizing at some length, anti-knock substances are discussed, inclusive of substances apparently dissimilar that have the same chemical constituents. The ignition point and fuel utilization are treated, followed by comments upon fuel studies that have been made, with accompanying indicator-cards. The future objectives of fuel research are outlined as being along lines of physical and of thermochemistry, the simple laws of elementary physics, and cooperation with the producers and refiners of the fuel.

IN again taking up the subject of fuels, I think that from every standpoint we have made wonderful progress in the past year. The laboratories that have been working on this problem have found out some things and so has the public; the refiners have joined in and I believe that we really have approached a position now where we know approximately what we are talking about.

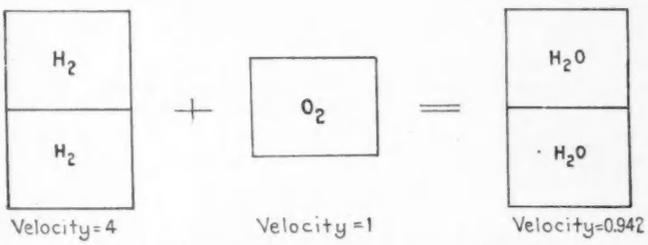


FIG. 1—COMPOSITION OF HYDROGEN AND OXYGEN

Even if we have not solved the problem, we have at least agreed that the solution we are seeking lies in a certain direction. I believe that we do not realize what a heterogeneous mental attitude we have had.

There is a deadline in the automotive industry. We might just as well recognize it as being our fuel situation. If we can get cooperation between the oil producers and the automotive engineers, so that we may know where that deadline is and so that no one steps over it unintentionally without knowing that it is there, I think we can do some really constructive engineering work. But we must take that deadline into account and know not only the quality of our fuel today and what its local distribution is, but also what its end-point is going to be in 3 to 5 years from now.

Two distinct problems are involved in this fuel work. First comes the question of multi-cylinder distribution. I believe that none of us can appreciate just how important a factor distribution is until we have taken a single-cylinder engine, in which the factor of distribution has been eliminated, and experimented with it. When

[1]M.S.A.E.—General Motors Research Corporation, Dayton, Ohio.

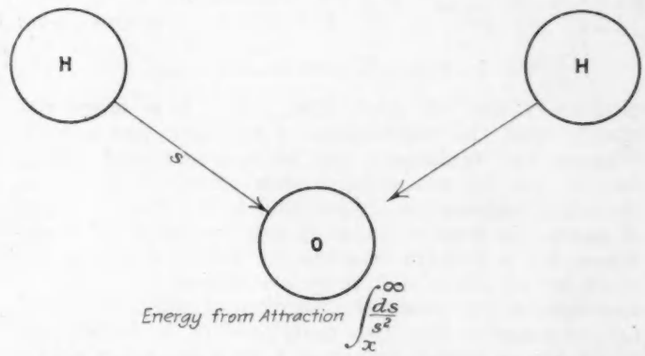


FIG. 2—GRAVITATIONAL ENERGY OF HYDROGEN AND OXYGEN

we get the variations in mixture, the power, the temperatures of the cylinder walls and the exhaust, and the temperatures of the water-jackets for lean and for rich mixtures, we will begin to understand what percentage of this problem belongs to distribution and what percentage to the chemical side of it after the mixture gets into the cylinder. We can run a single-cylinder engine economically when the air going into the carbureter is 10 deg. below zero fahr. We can run it at 15 lb. per sq. in. higher compression with air 10 deg. below zero than we can with air at room temperature; and yet, theoretically, we ought to have hot air on that kerosene carbureter. But we discover, as we adjust the carbureter for leanness and richness, that adjustment makes considerable difference from the standpoint of economy, as well as from the standpoint of power. After we get the proper adjustment, we presuppose that, if the carbureter measures off a certain definite and correct amount of fuel, the same correct proportion will land satisfactorily in all of the cylinders of a multi-cylinder engine. So, we have confused the problem of distribution with that of chemical constitution. These two things are entirely different. Usually, what helps the one, makes the other worse, but when they get hitched together, they make a fine pair.

Let us go back and define a few things; our nomenclature has got us into a wrong way of thinking. We talk about heat without having any physical conception of it. According to the best information available today, heat is nothing but molecular velocity. Whether a thing

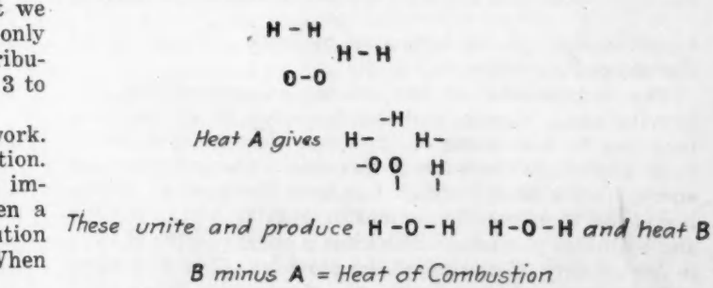


FIG. 3—HEAT OF COMBUSTION OF HYDROGEN AND OXYGEN

is hot or cold depends only on the magnitude of its molecular velocity. In considering heat we are dealing with motion.

Elementary Combustion

It will be interesting and of assistance in helping us to think about heat as a function of kinetic energy and a function of velocity and motion, to consider a most

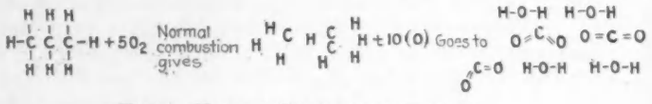


Fig. 4—Normal Combustion of Propane

elementary case of combustion. Fig. 1 is based primarily upon the combustion of hydrogen and oxygen. Suppose two containers, one of hydrogen and one of oxygen, are set alongside of each other. They are at the same temperature. According to the kinetic theory of gases, the kinetic energy of the gas inside of a container for a definite temperature and pressure is the same for all gases, and there are the same number of molecules in the container regardless of what the gas is. Let us suppose that two containers of hydrogen gas, which has an atomic weight of 1, or a molecular weight of 2, are alongside one container of oxygen, which has an atomic weight of 16 or a molecular weight of 32. If they have the same amount of molecular energy and an equal number of particles of each are in the containers, the hydrogen gas must move just four times as fast as the oxygen. When combustion occurs, or when the oxygen and hydrogen go together, the hydrogen is slowed down because the heavy oxygen molecule cannot run along with it at its former speed; so, some energy is given up by retarding the velocity of the hydrogen gas. But when oxygen and hydrogen burn and cool back to the temperature at which combustion began, the amount of gas has been reduced. Therefore, some energy has come by a change of volume. But the major part of that energy has come from another source, that is from the gravita-

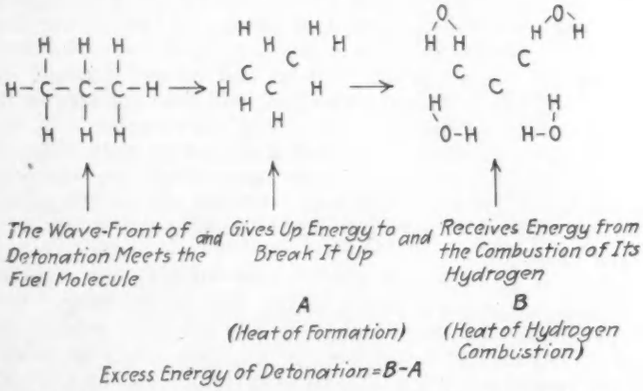

The Wave-Front of Detonation Meets the Fuel Molecule
and
Gives Up Energy to Break It Up
and
Receives Energy from the Combustion of Its Hydrogen
A
(Heat of Formation)
B
(Heat of Hydrogen Combustion)
Excess Energy of Detonation = B - A

Fig. 5—Diagram Showing the Abnormal Combustion of Propane

tional energy of the hydrogen molecule falling toward the oxygen molecule.

The components of the energy of combustion are gravitational, kinetic and barometric. It is very interesting to take some of the more elementary combustions and study them along this line. The gravitational energy is the energy which has been liberated by bringing closer together the centers of gravity of the oxygen and hydrogen particles. The kinetic energy is the change in the velocity of motion of the particles. The hydrogen was going fast; the oxygen was going slow. When they came together, the total mass slowed down considerably

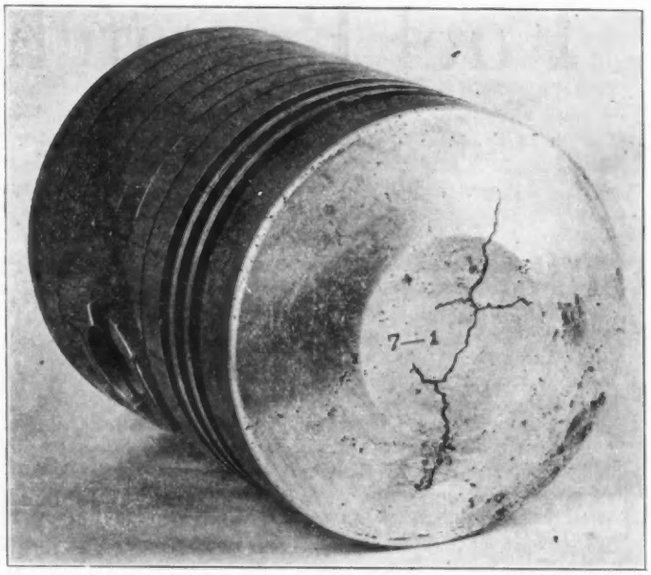


Fig. 6—A Liberty Engine Piston, the Top of Which Was Cracked as the Result of Being Subjected to Excessive Pressure

and that gave kinetic energy. The barometric energy is represented by the decrease in volume.

Let us consider an oxygen and a hydrogen particle as shown in Fig. 2 and that they are going to come into combination. A line integral of the distance between them, represented by s, is shown. It approaches from infinity, which is not necessarily very far, because these

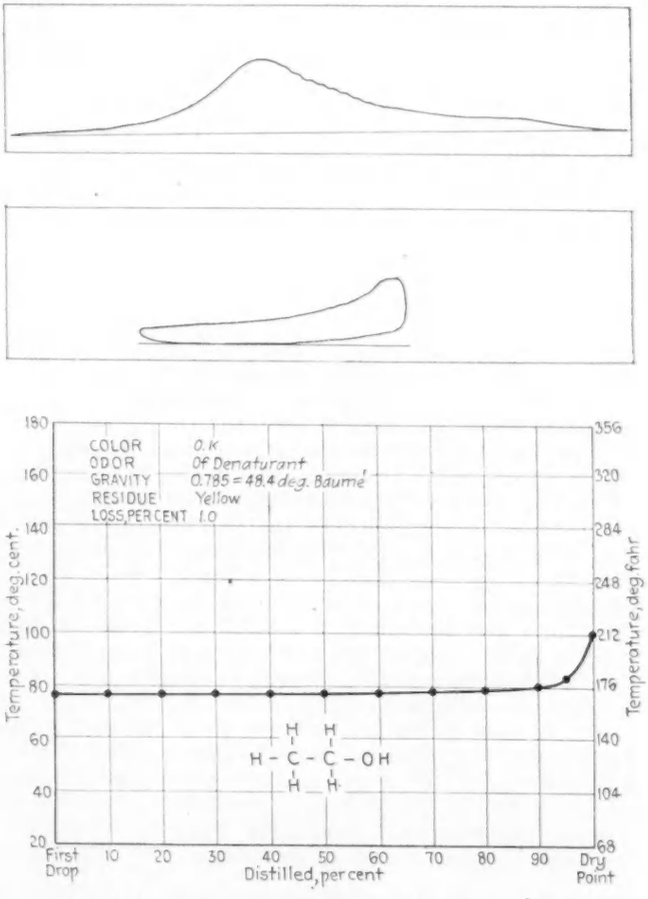
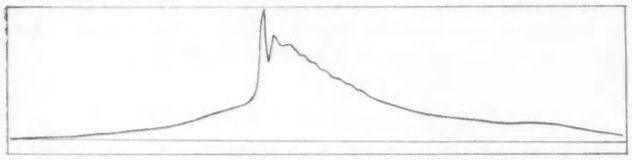


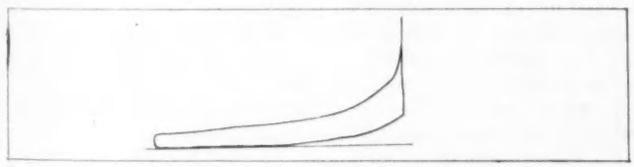
Fig. 7—Fuel Study of Commercial Denatured Alcohol

particles are very, very small and just a little bit is infinitely great. The amount of energy is the same in principle as that of the falling of a stone to the ground and is worked out in the same way. The mathematical formula for energy given in Fig. 2 is just a general expression of gravitational energy. The only reason we cannot figure it exactly is that we do not know the distance between the oxygen particle and the hydrogen particle. When we once get that, we will be able to know specifically what these things are. But we calculate the amount of energy liberated by this new set of static conditions exactly as we would the amount of energy developed from the falling of a stone. If those particles cause a great agitation as they come together, that represents heat; it is simply an oscillatory vibration of the particles as they bump back and forth.

Now let us consider the kinetic energy. As we expand a gas, we cool it. When we cool a gas, we simply take the velocity out of the particles. That is the only difference between a hot and a cold gas. If we consider heat as a type of velocity and that an engine is simply transferring molecular velocity of the gases into physical velocity of the pistons and the crankshaft, we will get a much clearer conception of what we mean by thermodynamics. If we boil down all of our present scientific knowledge, we come to a few fairly definite conclusions. One is that all the various phenomena of nature obey a few very simple elementary rules of mechanics. The laws of chemistry and physics and astronomy and all such matters are very delicately interwoven.

Let us analyze and find out what a charged particle is and what a catalytic reaction is, referring to the kinetic





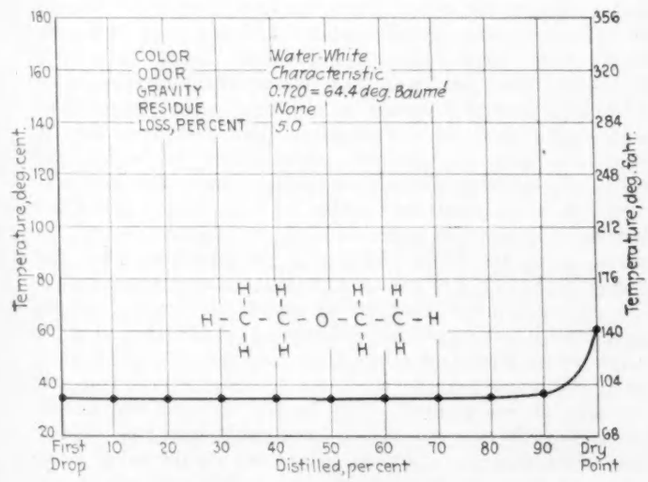
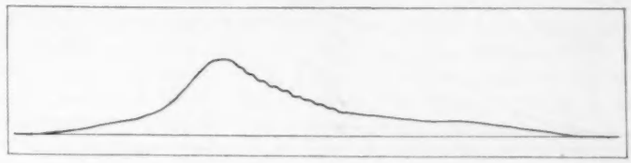
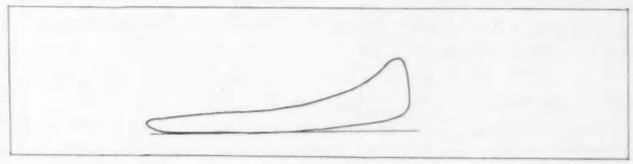


FIG. 8—FUEL STUDY OF SULPHURIC ETHER





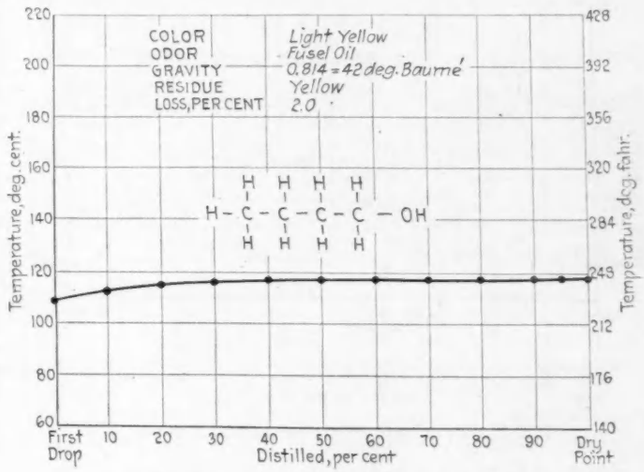


FIG. 9—FUEL STUDY OF BUTYL ALCOHOL

energy of combustion. The sensible heat in a gas is proportional to one-half of the energy, that is, to one-half the mass times the square of the velocity of the molecules of the gas. The various velocities have been measured. The hydrogen has a molecular velocity of 5560 ft. per sec. at 32 deg. fahr. (10 deg. cent.). The oxygen figure is approximately one-fourth of that. The water has a velocity which is the equivalent of the molecular velocity. The values of $\frac{1}{2}\ mv^2$ show us that we have left the difference between the sum total of all the kinetic energies of oxygen and hydrogen and the kinetic energy of the water vapor. That difference we have taken out is energy, so far as the slowing down of the gas particles is concerned, and that is a sensible amount of heat; it is 305 B.t.u. per lb. of hydrogen.

In reference to the barometric energy of combustion, this is just the difference due to the changing of volume. At 32 deg. fahr. and 14.7 lb. per sq. in. absolute pressure, 1 lb. of hydrogen occupies 180 cu. ft. and 8 lb. of oxygen occupies 90 cu. ft., a total of 270 cu. ft. But 9 lb. of water occupies 180 cu. ft. and the difference between the 270 cu. ft. occupied by the hydrogen and the oxygen and the 180 cu. ft. occupied by the water gives 90 cu. ft. as the reduction in volume upon the combustion of 1 lb. of hydrogen. Completing the analysis gives

$$(90 \times 144 \times 14.7) \div 778 = 245 \text{ B.t.u.}$$

This is the barometric energy of combustion of 1 lb. of hydrogen, and the 245 B.t.u. per lb. of hydrogen is not as much energy by about 30 per cent as was caused by the slowing down of the gas particles.

Fig. 3 illustrates the combustion of hydrogen and oxygen. What happens? First, we say that heat must

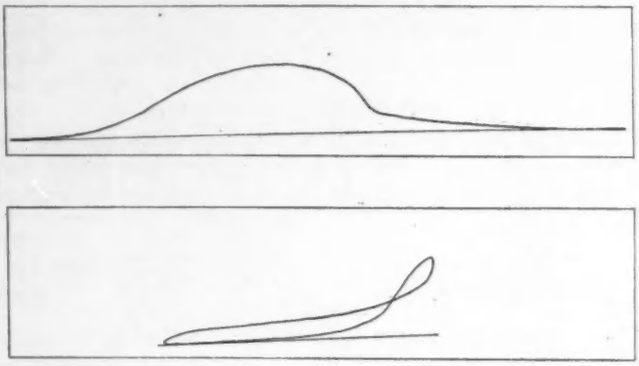


FIG. 10—FUEL STUDY OF CARBON BISULPHIDE

be supplied to break up the molecules. Let us not call it heat. Let us say that we must accelerate the velocity of that hydrogen particle to a point where its acceleration pressures are greater than its attraction. We have things here that are sticking together. We begin to shake the molecule back and forth and reach a point where the acceleration pressures become greater than the force holding the atoms together and they come apart. We have free hydrogen and free oxygen. Heat, *A*, must be supplied to break up the molecules as shown in Fig. 3; these unite and produce heat, *B*. That combination is given energy from the standpoint of kinetic energy, of barometric energy and of gravitational energy. So *B* minus *A*, gives the available amount of velocity or heat that we can use for something else. In this case it is 57,000 B.t.u. per lb. of hydrogen. The result is a liquid; it is water at 64.4 deg. fahr. (18 deg. cent.). I have followed through this rather elementary thing, the burning of oxygen and hydrogen, because I think that we as engineers should get acquainted with the problem in specific application rather than in perfectly general terms. We have been accustomed to putting the charge into an engine cylinder, saying that it exploded, and letting it go at that.

Fig. 4 illustrates the normal combustion of propane, which is a hydrocarbon gas. This is purely a theoretical expression. Instead of having a simple combination of molecular oxygen and molecular hydrogen, we have a combination symbolically represented as shown. This expression does not necessarily represent the facts in the case at all. When the hydrogen and oxygen unite, the same thing happens as when the molecular oxygen and hydrogen became one; so, there is a combination of energy represented here that may be many times greater than the simple energy of the hydrogen-molecule or oxygen-molecule combination. If we were using propane in an engine cylinder, the first thing we would need to do when a spark is put through it is to supply enough motion to that molecule to shake it apart, so that it becomes free hydrogen and free carbon. In the presence of oxygen, new gravitational conditions are set up and there are tremendous disturbances which we call heat. Calculating as before, the heat of combustion is 20,000 B.t.u. per lb.

We call that a normal combustion of hydrocarbon where the oxygen and hydrogen form water and the carbon and oxygen carbon dioxide. There is a condition under which we can bring oxygen, nitrogen and hydrocarbon together, where we do not get the perfectly normal combustion that results in water and carbon dioxide, but where the rapidity with which we accelerate these things is so great that we burn only a part. It is something like a load of bricks on a wagon; when we check the wagon too quickly the bricks slide off. In the case of an abnormal combustion, we start the one particle so fast that the other cannot follow. Then we get an entirely different result. In the abnormal combustion shown in Fig. 5, we get a much smaller amount of heat with the liberation of free carbon, instead of getting a large number of heat units as before. If we put propane gas into an engine, we would never get a condition of abnormal combustion such as this, nor would we get a knocking condition, because we would have in the engine a diluting element in the form of nitrogen gas. But if we change the mixture, if instead of air and propane in the engine cylinder, we throttle out the nitrogen and begin to let into it a little oxygen, we immediately meet the abnormal condition shown in Fig. 5. So, no matter how excellent the specific gravity of the fuel is, we can always reach an abnormal condition with it by accelerating the combustion.

THE NECESSITY OF THEORIZING

The matters I have explained thus far relate to the elementary mechanics of combustion. Any thermal chemistry contains the same information; there is nothing new about any of it. There is no trouble in getting this information; the trouble has been in the nomenclature which has been used. We use the terms "heat" and "light" without having a physical conception in our minds as to what these things really mean.

The theory of all of this may be 100 per cent wrong, but that makes no difference. If we never had theories about things, we would never arrive at radical results. To illustrate, Mr. Midgley and I had the very beautiful theory that what causes kerosene to knock is that it enters and becomes vaporized due to the heat that is in the cylinder when it comes in, and that when compression begins, the heat of compression does not develop fast enough to keep the kerosene from liquefying again and the mixture slows down to a point where the kerosene forms in little particles on the cylinder wall. We knew that early spring flowers are red on the bottom of the leaves, so as to utilize the maximum amount of radiant energy from the sun and get a little more heat. Therefore, we concluded that if we dyed fuel red it would absorb more energy and consequently not condense so easily. The chemical laboratory had no oil-soluble dye, but it did have iodine. Iodine colored our fuel red and that was all we wanted. The iodine stopped the knock, but it did not stop the knock because it was red. However, if we had not had that theory we would never have found out about these matters. So, I think we ought not

to criticize a man for having a theory. If he has no theory, he will not progress very far.

We know that very definite chemical laws govern existing fuels and that many things can be done in making use of them. This subject is presented with the idea of laying before automotive engineers what we have found out and what we are thinking about. We realize that we are so inadequately equipped, mentally and physically, to cope with all the ramifications of this problem, that we need to show the progress made from year to year and to get all automotive engineers to think along this same line. It makes no difference whether a single thing I have said is right or wrong. If I can convey the point of view of realizing that this problem exists, I shall be satisfied. I have been accused recently of trying to rewrite the theory of explosives. We are not trying to rewrite anything; we are simply trying to utilize facts. We know that engines knock. That is not a theory any more. It is a fact that we get crankcase dilution. We simply try to take the facts, analyze them, find out the cause and determine what can be done to eliminate it.

Anti-Knock Substances

The anti-knock substances are not nearly on a commercial basis as yet. They are more nearly on a commercial basis now than they were a year ago, because people understand the situation better. They have many other values besides that of stopping the knock; they are carbon solvents. We analyzed many carbon deposits. We found they were made up of free carbons, a very heavy hydrocarbon and a very small amount of a hydrogen-oxygen carbon, and that a binder which is about the same as an ordinary varnish holds this hydrocarbon and the free carbon together. It happens that these anti-knock substances are all varnish-removers; consequently they dissolve out the binder part of the carbon deposits and the remainder blows away.

There are many theories regarding detonation. Fig. 6 shows a piston taken out of a Liberty engine; the top is cracked. We have seen some pistons, worse than this one, that have been blown in. We do not know what hit the piston; an explosion-wave or a detonation. The fact is that the piston was knocked in.

Difference in Molecular Structure

We have a number of apparently dissimilar substances that have the same chemical constituents. Ordinary rubber, such as is used in automobile tires, and naphthaline are two apparently different substances. One is a very tough, tenacious material and the other is a crystalline substance; but each is composed of hydrogen and carbon. I mention them to show that the same two

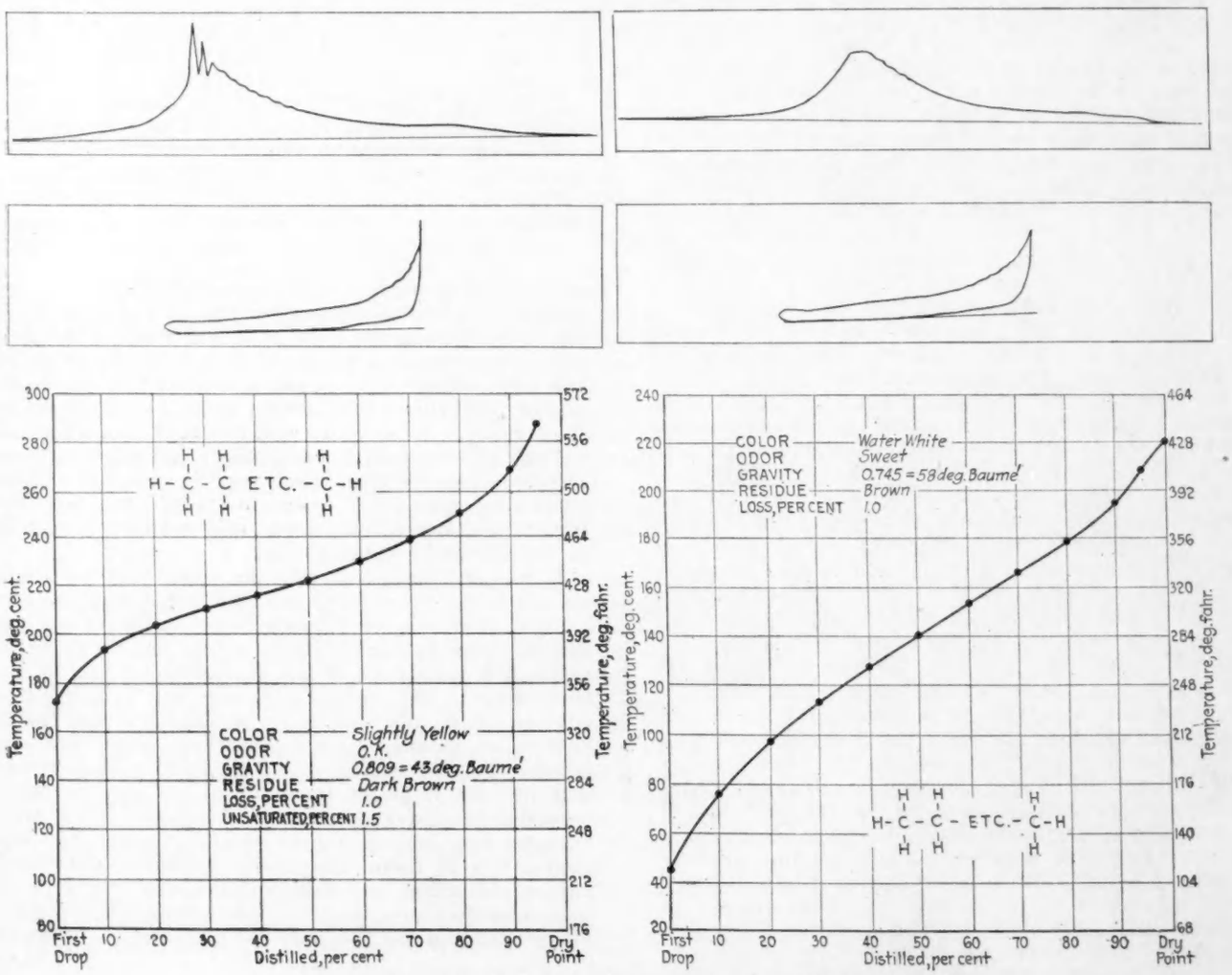


FIG. 11—FUEL STUDIES OF TWO FUELS OBTAINED FROM PENNSYLVANIA CRUDE OIL
The One at the Left Is for Kerosene and That at the Right for Gasoline

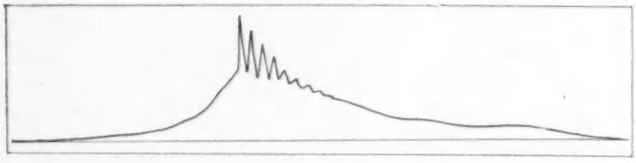
things can be put together in such ways that their molecular constitutions are enormously different. Another instance is that of two liquids, benzol and cyclohexane, the latter being nothing but benzol with an added amount of hydrogen.

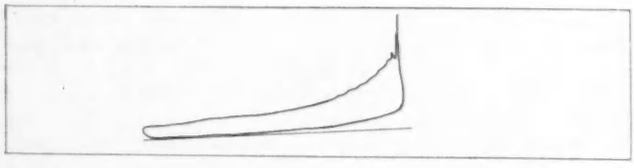
The crystalline substances, naphthaline, rubber and paraffin, which is a more or less amorphous form of hydrogen and carbon, are all the same; they are just made up in different combinations. That is why we must realize that the chemical constitution of fuels represents so many different things.

Ignition Point and Fuel Utilization

There has been much discussion as to the ignition point. The autoignition point is only the point at which we reach the proper condition of molecular velocity; it has absolutely nothing to do with the phenomenon of knocking. Carbon bisulphide has such a low autoignition point that we can heat it with a hot wire and explode it. If we put that into an engine, it absolutely will not knock, and yet its autoignition point is only 140 deg. So, autoignition, or preignition, has absolutely nothing to do with the phenomena we are talking about.

The question of the utilization of fuels to-day involves two distinct things. One is the matter of getting the right mixture into the cylinder. This has no relation to the physical constitution of the fuel, except insofar as it is hard to segregate and nebulize to get the right amount by weight of fuel and air into each cylinder. After





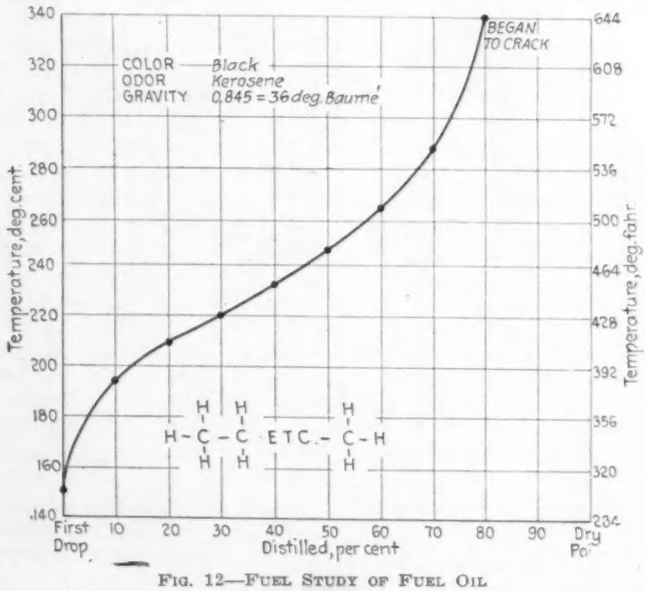
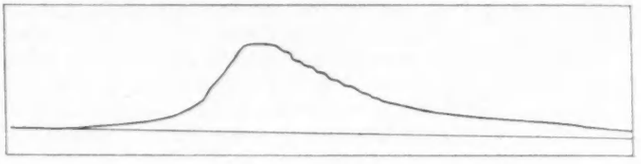
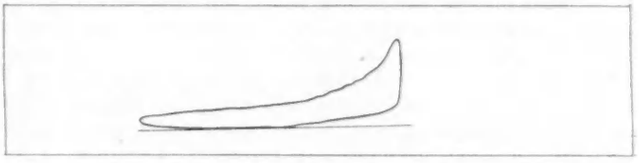


Fig. 12—Fuel Study of Fuel Oil





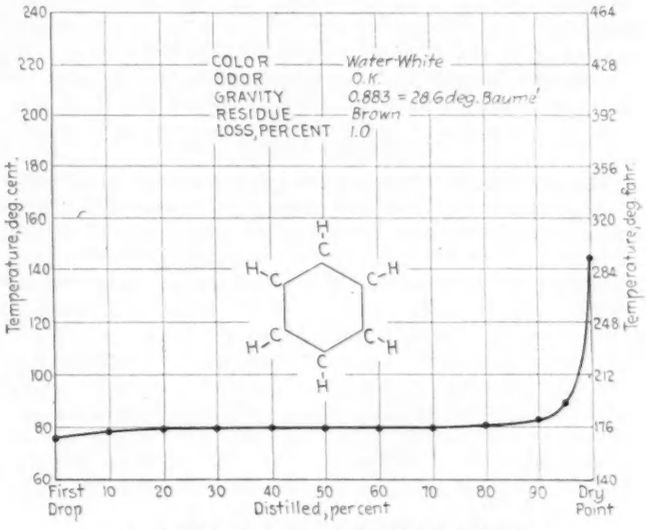


Fig. 13—Fuel Study of Commercial Benzol

experimenting with a single-cylinder engine, the very distinct conclusions are reached that it makes no difference whether the fuel goes in as a dry gas, a nebulized gas, a vaporized gas, or any kind of gas; that if we get the right weight of fuel and air into the cylinder the mixture will burn under certain definite conditions; that the conditions under which that fuel burns are a function entirely of its chemical constitution; that abnormal combustion, which we term "knocking," is an entirely different phenomenon from preignition; and that the autoignition point of a fuel may or may not have something to do with its knocking ability.

If we can only get it into our minds that we should quit thinking of heat in any other terms than those of molecular velocity, we will have helped ourselves one step farther along in our ability to realize and to bring together the loose ends of the fuel problem. All of the phenomena of physics and chemistry can be utilized in engines. It is only because we perhaps have not had to analyze the details of these operations, more than was necessary at the beginning of the automotive industry, that we have forgotten them. That has been perfectly natural in the development of this business. In the early days we had fuel of a high volatility. All that was needed was to make true engine cylinders, well fitted pistons and valves and then install almost any type of mechanism to supply the fuel. The engine ran very well. The volatility of the fuel began to drop and we began to

(*Concluded on page* 343)

The Relation Between the Highway and the Vehicle

By B. B. BACHMAN[1]

WASHINGTON SECTION PAPER

AFTER reviewing briefly the general history of highway and motor-vehicle development, the author discusses highway and motor-vehicle relations in regard to the respective merits of constructing highways of relatively short mileage suitable for the operation of very heavy traffic and greater mileages of roads of a character that will make necessary the limiting of the vehicle load to protect them from undue deterioration. The maximum weights allowable for horse-drawn and for both light and heavy motor-vehicles are commented upon and the question of whether to have restricted or unrestricted motor-vehicle traffic is discussed pro and con.

The advantages of having adequate highways and suitable vehicles are reviewed and restrictive legislation in its relation to wheel loads and to interstate traffic is considered.

FOOD, shelter and clothing are the fundamental requirements of mankind, in the order of their importance. A human being can obtain each of these for himself to an extent that will support existence, independently of any assistance from others and even under rather adverse conditions. There are probably no examples of the individualistic savage extant. The next step from this individualistic state is the small community where the individuals divide among themselves the performance of those functions that provide for the composite need. The size of such a community is limited only by the ease and speed of communication. Even the most uncivilized peoples have progressed to the community state, although it may be in the crudest form. These communities remain small, limited in their prosperity, burdened with disease and filled with tribal jealousies so long as their means of communication are limited to messages from drum-beats or signal fires, or to the use of beasts of burden that travel over natural pathways. The military highways of Rome, the fleets of Venice and Genoa and Great Britain, the railroad, the automobile and the airplane are the means by which mankind has widened its perspective and, conquering the wilderness, has built up the system of industry which is the framework on which civilization depends.

The beast of burden is represented by sufficiently diversified types to make it possible to find one suited to almost any natural condition of terrain. In many cases beasts of burden can subsist on the products of the country through which they are traveling and their limitations of usefulness are therefore speed and fatigue. These limiting factors are reduced by the preparation of highways that need be only of a relatively elementary nature. But the railroad immediately enters the field of extensive preparation, that of the roadbed involving for most economical operation suitable capacities of rails and ballast, a limitation of gradients and adequate bridges. The manner in which these requirements are met varies with conditions. To meet them in a manner requisite for main-line construction necessitates a large investment of capital that, naturally, is justified only when the anticipated earning power will insure a sufficient return. It is for this reason that the early days of railroad building in the United States witnessed the construction of many miles of roadbed that was ridiculously crude when viewed in the light of present traffic conditions. The need at that time was not for a few miles of high-grade construction, particularly in the transcontinental field, but for a large mileage of anything that would serve the immediate need, awaiting the development of the Country with a coincident growth of traffic that would warrant a greater investment. Even today there are numerous miles of branch lines on which the traffic density does not warrant the highest type of main-line construction. Manifestly, the same weight of trains cannot be used on these lines, nor can the same speeds be attained as on the main lines. Under present-day conditions, therefore, we find heavy equipment operating in the dense traffic zones of the railroads at high speeds over easy grades having heavily constructed roadbeds, and lighter equipment operating at more moderate speeds on branch lines and feeders.

The advent of the automobile in this Country found road development in the areas outside of metropolitan districts almost at zero. All of us whose automobile experience dates back even 10 years have been bumped over water-breaks, mired in hub-deep mud and stalled in snow-banks. Gradually, the construction of roads has come about here and there throughout the Country that has made automobile travel a comfort and a delight. These road improvements have consisted in greater part of providing a reasonably hard, smooth surface. In some places grades have been lessened and sharp turns and dangerous crossings eliminated. The requirements for this class of traffic are for a highway wide enough to permit passing other vehicles at a reasonable speed, a surface that is smooth but not slippery when wet, and a strength of road and bridges sufficient to support passenger cars on pneumatic tires. Furthermore, the rapid increase in the use of these vehicles in suburban and rural districts has created in almost every locality a demand for highways improved in this manner. This has resulted in a need for the construction of an apparently staggering amount of road mileage. The cost of this construction naturally depends upon its nature, and this in turn depends upon the character of traffic that will use it.

Following the development of the passenger vehicle, the automobile industry, aware of the demand for this apparatus as a transporter of merchandise, entered the field of commercial-vehicle manufacture. In the beginning, we find the truck appearing as a relatively small vehicle for delivery purposes and timidly reaching out to extend the radius of operation beyond the zone to which it had been limited by animal-drawn vehicles. Then came the development of the heavier vehicle principally used in hauling larger shipments over comparatively short distances, mostly within city limits. Examples of its use are deliveries from wholesale warehouses to retailers of building materials and the like. The successful operation of these earlier and lighter-type commercial vehicles created a demand for larger vehicles, the build-

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ing of which was made possible by the coincident advance in knowledge of mechanical construction. At the same time the increased radius of operation over that of horse-drawn vehicles, made possible by the use of light commercial vehicles, resulted in the demand of operators for the use of the heavier vehicles in competition with railroads. One of the earliest instances of this sort of competition was the transportation of furniture and household goods by motor van over distances of several hundred miles.

The congested condition of railroad facilities during the war furnished the opportunity to put the motor truck to the acid test as a tool for long-distance transportation. We are all proud of the accomplishments recorded; nevertheless, many things were done during that period of necessity that are not warranted by strict considerations of efficiency and economy, and many problems were brought to the attention of the builders of trucks and of highways, of the general public as well.

Highway Development

We, as a Nation, had gradually progressed from the ordinary dirt and loose-stone country-road to improved highways of various types in the more thickly populated States and in the vicinity of large cities, but these roads had not been put to the task of carrying modern truck traffic. It was therefore a rather rude shock to note the condition of some of our pet roads after the winter of 1917-1918. It is only natural that observers of the condition should react differently and largely in accordance with their interests. The taxpayer, the operator of passenger vehicles and the departments charged with maintenance and construction of roads have, in many instances, expressed the opinion that a limitation of loads is essential. The builders and operators of motor trucks have advocated consideration of the vital necessity of constructing more durable roads, the character of which would permit the operation of heavy vehicles upon them, and to support their contention have pointed to the many economic factors favoring such operation. Undoubtedly, there are meritorious features on each side of these arguments, and it is highly probable that the true solution for the present at least lies somewhere between the extremes.

The question that we are facing today is whether we shall spend the money that is available in the construction of relatively few miles of road suitable for the operation of very heavy traffic, or in the construction of a greater mileage of roads of a character that will make necessary the limitation of the vehicle load to protect them from excessive deterioration. This is in many respects the same problem that faced the Country in the early days of the railroad, and an analysis of it requires answers to a number of collateral questions.

Probably the first question is, Who will be the users of these roads? Horse-drawn vehicles are slow-moving, equipped with metal-tired wheels and, in the heavy class, in many instances unsprung. They are disappearing rapidly in the industrial districts and will probably continue to disappear at an accelerated rate. They may be replaced to a large extent in agricultural districts by motor vehicles for passenger conveyance, but still are being used to a large degree for other purposes. While the motorization of the farm is in progress, a long time will be required to displace the horse, even with a greatly increased production of motor vehicles. Therefore, viewing the matter on a national basis, it seems that this class of traffic is of great importance.

The maximum weight of a horse-drawn equipment is probably not over 12,000 lb. except in rare cases. A road equipped with bridges capable of sustaining this load, with a surface that will provide a footing for the animals in bad weather and of a character to resist the chipping action of hoofs and the cutting of metal tires, will meet, speaking generally, the requirements of this class of equipment.

Light motor-vehicles as a class include both passenger cars and trucks up to a maximum weight of 12,000 lb., with their burden. All passenger cars and trucks up to this capacity to an increasing degree are being equipped with pneumatic tires and with adequate spring-suspensions. The road requirements for this class of vehicle are in most respects similar to those of the first class, the only difference in operation being with regard to speed. It is very probable that the difference in tire and spring equipment will balance the last named factor to a large degree.

The heavy class includes motor-vehicles of a gross weight of from 12,000 to 20,000 lb. This class is to a large degree equipped with solid tires and also, as in the case of the second class of vehicle, with adequate spring-suspension. Vehicles in this class of from 3½ to 4-ton, and 5-ton capacity in some cases, are transportation units that, while having great efficiency and proved usefulness, are still within the weight limits that do not make necessary the construction of roads of extremely high capacity.

Finally, as a fourth class, we have the larger trucks of 6 to 7½-ton capacity that will weigh from 26,000 to 30,000 lb. with bodies and load. While these sizes of unit have proved to be of considerable value in solving many transportation problems, the operation of the vehicles at high speed, particularly in the late winter and spring months, has resulted in great damage to many roads not of the very highest type of construction.

Restricted or Unrestricted Traffic?

This condition has aroused the feelings of the other users of the highways, and caused the authorities charged with highway supervision to look with some disfavor on this class of traffic. Recent legislation has taken cognizance of this fact, and we find that in many States a limit of 28,000 lb. is set as the maximum total burden for one vehicle, and in some States less than that. At the same time, the highway authorities in some States have availed themselves of the authority vested in them to make temporary restrictions effective for the winter months that reduce this limit to still lower figures. These restrictions cause no inconvenience to the first three classes of road user, but naturally the user who is restricted in his operation is very much disturbed and also the producer of this apparatus is concerned, as it may take the form of reducing his sales.

Many plausible arguments are presented to the effect that roads and bridges should be constructed with sufficient capacity to accommodate a relatively unrestricted traffic. It is pointed out that in the last few years the transportation of merchandise by trucks over relatively long distances was all that prevented the acutely congested condition of the railroads from causing an industrial calamity. While it is generally agreed that under normal conditions it is unlikely that the truck can compete with the railroad for distances of over 50 to 100 miles, dependent upon conditions as to climate, road, topography and the like, still it is argued that, in view of the insurance factor, if adequate highways were in existence in case of a recurrence of conditions such as existed during the war, we should make our plans with these things in mind. Then the question of the military value of roads is presented, and the necessity of giving

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due consideration to the part that highways and truck transportation played in the critical periods of the war, notably in the defense of Verdun and Paris. All these arguments contain a considerable amount of logic and no one can doubt their force. There is this fact that must be considered, however: The problem we are contemplating is largely one of immediate necessity and not of future requirements. If we had a great mileage of adequate roads in this Country and were considering what we should build for the future, or if we were studying the construction of a direct revenue-producing system such as a railroad, these factors could be considered in a different light. But we are far from having even an approach to an adequate highway system, considering the matter nationally, and the question of finance is serious in these days of high taxation. The great need for heavy-capacity roads is to a large degree in the industrial areas, but the taxes would fall with equal weight on the small community and the farmer. Rural people are in many cases annoyed by dust and water-breaks in summer, and by having to flounder through mud in winter. They demand relief and care little how great the capacity of the road is, so long as it endures and supports their passenger vehicles and trucks.

In view of all these factors and for the best interests of all, it seems that the logical answer to the question is to build roads, to the limit of our resources of labor, material and money, of such a character as will secure the greatest mileage, and of width and carrying-capacity consistent with the needs of present traffic and that of the immediate future. For metropolitan areas such a program should provide roads capable of caring for vehicles of from 26,000 to 30,000-lb. overall weight, with a possible limitation to a lower figure in the winter months or whenever local conditions make such action temporarily necessary to save the roads. Between large industrial centers that are relatively not far apart, such as those along the Eastern seaboard and along the shores of the Great Lakes, there should be trunk-lines of the same character. Outside of such areas of dense population, where the volume of traffic is smaller, trunk-lines connecting and forming through routes of sufficient capacity for medium-weight vehicles, not over 20,000 to 24,000 lb. gross, should serve admirably. Connecting and community roads in the great rural areas, if constructed on the smaller-capacity basis of 15,000 lb., should be entirely adequate in comparison with present facilities.

As to what the result would be if such action were taken, from the standpoint of the effect on the user and the communities through which these improved highways would run, a complete list of the benefits would probably sound like a fairy tale. It is only necessary, however, to view the change in conditions that has resulted from improved highways to see that life in rural communities has become more attractive because of the increased opportunity for social intercourse. Farms are improved on account of the possibilities of transporting their products to more profitable markets; and such conditions result in many cases in the reoccupation of abandoned farms and their being brought again into a state of active production. From the standpoint of education, the influence of good roads has resulted frequently in the consolidation of small schools, the pupils being transported by omnibuses. This has had the effect of creating a community spirit, increasing the efficiency of the teachers by making possible the grading of the pupils in a more modern and efficient way, and insuring continuous schooling for many children, which was impossible under the old conditions. With regard to the motor-car builder and distributor, those in the passenger-car and medium-duty-truck fields would be greatly benefited. The heavy-duty-truck field also would be broadened, possibly not so much as those directly concerned might wish, but still to a considerable degree. Another phase of the last named consideration is that, given a more general distribution of roads of the nature outlined, it will be possible to increase the ratio of burden capacity to vehicle weight. This is true of all classes of motor vehicle. The reserve power and strength that must be provided to cover present road conditions could, and undoubtedly would, be reduced materially if hard, smooth-surfaced roads of relatively low gradients were common. Such a condition would go a long way toward reducing operating expenses, due to more efficient returns from expenditure for fuel, tires and the like, and to reduction in maintenance and repair costs.

Present Highway and Vehicle Needs

To sum up the whole matter, as a Nation we need thousands of miles of roads. These roads are an immediate necessity and should be constructed as a result of careful, broad-minded, constructive planning. Many roads that have been constructed at great expense have no economic justification for their existence, and many communities are still laboring under the handicap of inadequate roads. In road construction the linking up of industrial areas should be taken into consideration. Consideration should be given also to providing agricultural districts with outlets to profitable markets. Long-distance highways of expensive construction that serve no economic purpose should have no place in our present plan. The creation of such a system will require a concentration of our resources of labor and money to the utmost to meet the urgent immediate necessities. It is necessary, therefore, that the problem be considered from a national viewpoint with the legitimate needs of everyone in mind, and without the entrance of any taint of class consideration.

In many communities where the cost of road construction is apparently an unsurmountable obstacle, the real difficulty probably lies in the fact that taxpayers as a body feel that the road improvements that are being demanded will minister to only a limited class. The fallacy of this viewpoint can be demonstrated readily by a comparison of the speed capacity of horse-drawn and motor-driven vehicles. The transportation radius can be increased from two to four times, or the time occupied in covering a given distance can be reduced to one-half or one-third when motor-driven replace horse-drawn vehicles. The economies that can be effected, together with the increased profits that can be made by reason of this saving in time, will more than justify the cost of the construction. Outside of the industrial-district and trunk-line construction already mentioned and in view of the road and bridge requirements considered ample for animal-drawn traffic, it does not seem that a much more expensive type of road is necessary to serve the needs of motor traffic, and what increase in cost there is will be amply justified in the light of what has been said. On the other hand, it does not appear to be justifiable to attempt the construction of roads of a capacity capable of carrying the extra-heavy motor-vehicle traffic everywhere regardless of conditions, for such a procedure will not only entail unnecessary expense but tend to retard the construction of vitally necessary roads, on account of the opposition that such a program would encounter. With a rationally graded system of road construction, the truck as an efficient tool of commerce can be developed along

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lines that will be consistent with such a program, without hampering either the manufacturer or the user in their respective fields.

Restrictive Legislation

There is a crying need for the coordination of legislation relating to the control of highways and traffic, particularly interstate traffic. This probably will be secured only under Federal supervision. In many instances highways that are excellent within a State's boundaries are neglected near the borders or do not connect with similar roads in adjacent States, thus breaking down the possibility of through traffic. Another factor is the specification of allowable load per wheel and per inch of tire width. With regard to the wheel load, this is entirely proper because it provides information that the highway engineer must use in estimating the requirements of foundations and the beam strength of the road. It is essential that the specification should be on uniform lines in all States. The provision with regard to load per inch of tire width seems to me to be based entirely on false premises, and the way in which it is applied at present is wrong. Solid tires have the greatest width when worn down to the base, and yet there is so little cushioning effect when they are in this condition that they are much more harmful to the road than a narrow tire with sufficient thickness to provide a cushion. This seems self-evident, and still we find the per-inch-width-of-tire provision in almost every law, with varying methods of application, and practically no provision against the use of worn-out tires that are harmful not only to the roads but to the vehicles as well.

ACCURATE THREAD-CUTTING

IN tapping holes for ordinary screws, such as those used in holding machine parts together, good fits are chiefly dependent upon the accuracy of the tap. As the tap is generally a rigid tool and non-adjustable, it will tap a hole approximately to its own size; but when the lead has been found to be inaccurate, due to distortion in hardening, there has been in the past no practical means of correction to bring the tool back to its original condition of accuracy. Dies used for threading screws are generally adjustable as to diameter, and because their chasers are short, they are easier to control in hardening. For this reason screws with fairly accurate leads can be cut with commercial dies.

Absolute accuracy of the lead in taps is unknown, and even the diameter and shape of thread is very hard to maintain. Tolerances are therefore established on fits between the threaded parts. By the use of such equipment as the Hartness comparator it is a simple matter to determine the accuracy of the lead of threaded parts.

Lead of the Screw

When the lead in a nut varies from the lead in a screw, there is hardly more than one thread in contact. When the nut is tightened, this one thread yields until one more thread is in contact, and by further tightening it may be possible to get a number of threads to assist in carrying the load. However, the engagement between the threads of the nut and the screw extends over only part of the length of the thread in the nut; and where there is contact, the threads have been distorted. When the screw is exposed to the load, due to the pressure brought upon it by the machinery parts that it is supposed to hold together, it is liable to work loose, because of insufficient contact between the threaded parts.

It is often attempted to overcome this difficulty by employing lock-nuts as substitutes for accuracy in the threads. Fine-pitched threads are easier to force into contact with each other than coarse-pitched ones; but the finer threads are also easier to destroy, and when the two parts are hardened, these finer threads are often broken off altogether. The original trouble of the wrong lead of thread has never been fully overcome by the employment of any substitute. On the other hand, if the lead in the nut and the screw are the same, all the threads in the nut are in contact with the screw. In tightening the nut, no yielding will take place, and the friction obtained throughout the length of the thread will keep the nut from vibrating loose or the thread from yielding. Even if a nut fits loosely on the screw, but has the same lead as the screw, it will hold tightly with moderate pressure.

Every experienced engine-builder has had trouble in fitting studs into cylinders and similar parts. The stud is screwed into a tapped hole. Generally it fits loosely into the first threads and tightens after being screwed in further. The tightening is due to the difference of the lead in the two members, and it is taken for granted by the workman that he has a good tight fit. When the cylinder head is mounted and the nuts tightened on the stud, the threads of the stud in the casting will yield under the pressure; but when the cylinder head is to be removed and the nuts are taken off, it is often found that the stud will come out with the nut instead of staying in the tapped hole in the cylinder. If the lead of the thread in the hole and on the stud were the same, the stud could be made to fit throughout the length of the hole and every thread would then do its part in holding the stud firmly in place.

The methods for making gages for measuring and inspecting screws have developed considerably during the last fifteen years. When good work is required, the screw-maker is held down to very close limits. In many cases not even a maximum and a minimum gage are used for testing a screw-thread. The screw in that case is expected to fit with an even friction in only one gage. As the die is adjustable, it is possible to meet this requirement. But is it not incongruous that after having made all of these fine screws and inspected them with this very fine gage, they are put into holes that are tapped with a tap that often has a thread with an inaccurate lead, and that has a fairly large tolerance on its diameter? Furthermore, all of the holes for these fine screws are not always tapped with the same tap, and when screws are made to fit fairly satisfactory in a hole tapped with one tap, they will not fit a hole tapped with another tap, although the taps are supposed to be of the same size.

In addition, taps are often slightly bent in hardening, the lead being a little longer on the convex side than on the concave side; and although the diameter may be fairly close to size, as measured with a ball micrometer, it will not tap a hole of the same size as its own diameter on account of being bent. I have had the experience with taps measuring very nearly the same in diameter, of one tapping a larger hole than the other because it was straighter than the other. I have come to the conclusion that the majority of difficulties in thread-fitting are due to the inaccuracy of taps. If taps are made accurate in lead and diameter, most of the troubles encountered in fitting threaded parts are likely to be overcome.

Great efforts have been made by committees of experienced men to eliminate the errors in the various types of thread-cutting tools; and great strides have been made in establishing tolerances within so-called "commercial limits." If the market can be supplied with an accurately made tap, this problem will solve itself; and if screws and threaded holes can easily be held to a predetermined size, according to standards in vogue, the committees will be relieved of the task of establishing tolerances that will suit everyone's requirements.—B. W. M. Hanson in *Machinery*.

Automobile Frame Stresses

By Ethelbert Favary[1]

Metropolitan Section Paper *Illustrated with* Diagrams

FOLLOWING a review of some of the factors that are productive of excessive weight in a motor vehicle, which causes fuel wastage, and a statement that a more thorough standardization of frames and other parts would eliminate much of this waste, the author presents in detail frame-stress calculations intended to enable the designer to proportion frames and parts with this end in view. Shearing stresses are treated in a similar manner and for a similar reason, use being made of diagrams that facilitate analysis of specific instances cited and being inclusive of a table of bending-moments derived from the diagrams.

Laboratory tests of the ultimate strength, elastic limit, yield-point, elongation and reduction in area of materials are then described in some detail and the results obtained stated.

THE stress in the metal of channel frames varies greatly in trucks produced by different firms and also in the several models of the same builder. Trucks of the same capacity having vastly different wheelbases often are found to have channels of the same size. It is true that sometimes a better grade of steel is used by the maker in his trucks of larger capacity when the section is kept the same. Obviously, if the stresses in the frame are not too high for a 7½-ton model, the frame of a 3½-ton truck, having a channel of the same cross-section, is certainly too heavy. It can be argued, however, that the builder has certain dies for forming the channels and that it is less expensive to construct a 3½-ton truck with a heavier frame than to have new dies made for a lighter frame. This may be true, but it means more dead-weight for the same carrying capacity. What is true of the frame is true of other parts of the machine, and the amount of excessive weight often is considerable, implying a constant waste of fuel and material that might be saved. It would seem that a more thorough standardization of frames and other parts would eliminate much of this waste. The Society of Automotive Engineers is doing excellent work in this direction, and the more readily producers cooperate with the Society, the more the automotive industry will profit.

Frame-Stress Calculations

The calculation of frame stresses, although simple, is a puzzle to some. This paper is taken from the regular lessons that are given to the second-year students of motor-vehicle engineering at Cooper Union.

Consider a 2-ton truck with a wheelbase of 148 in. and having the loads located as shown in Fig. 1. The 4000-lb. load and the body weight of 960 lb. are distributed over a frame length of 124 in.; one-half of this weight, 2480 lb., is resting on each side-member. The load is not always evenly distributed in practice, but it can be so considered for present purposes; but it should be remembered that the factor of safety must be sufficiently high to compensate for uneven load distribution. The driver's seat is 10 in. in front of the body and the gasoline tank is located underneath it. Assuming two persons and the gasoline to weigh 400 lb., we have one-half this load, 200 lb., on each side-member. The unit powerplant, with radiator and water, is assumed to weigh 1000 lb., 60 per cent of which rests on the rear supports and 40 per cent on the front, the radiator being situated above the front engine support; hence, 300 lb. and 200 lb. respectively are resting on each side-member at the points indicated in Fig. 1. This does not include the load due to the torque when applying the brakes and locking the wheels, which will be referred to later. Thus we have a total load of 3180 lb. on each side-member, supported by two semi-elliptic springs.

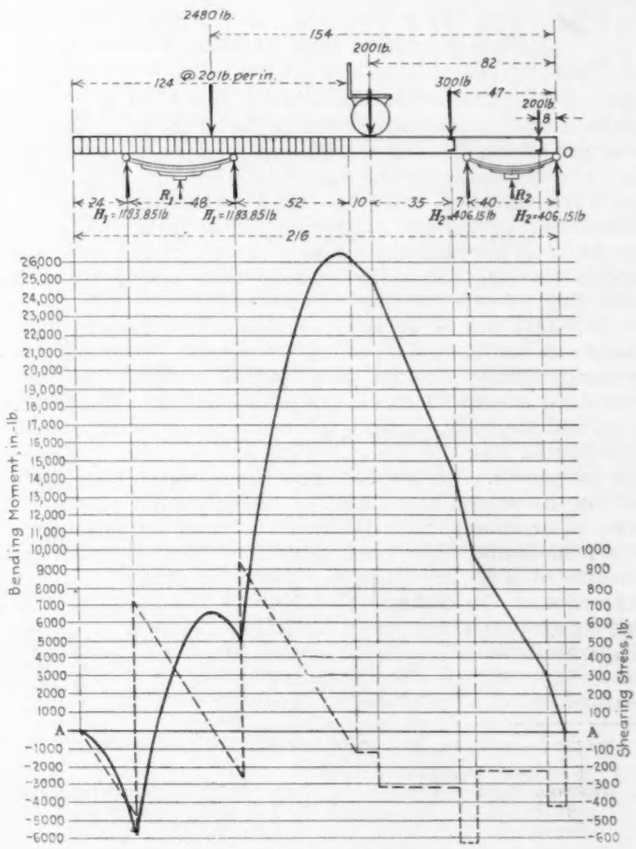


Fig. 1—Graphic Chart of the Frame Stresses in a 2-Ton Truck Having a Wheelbase of 148 In., and a Load Distribution as Indicated in the Upper Part of the Illustration

The first step is to find the reaction at each spring-eye.[2] The distributed load and the body weight are considered for this purpose as being concentrated at their center of gravity, which is 62 in. from the rear end of the frame; as stated, their weight on each side-member is 2480 lb. Denoting the reactions that are exerted

[1] M.S.A.E.—Consulting engineer, lecturer on motor vehicle design, Cooper Union, New York City.

[2] See the *Automobile Engineer*, August, 1912, p. 233, for an analysis of frame stresses by C. F. Cleaver.

against the frame through the spring-eyes by R_1 and R_2 respectively, the load on each side-member is

$$R_1 + R_2 = 3180 \text{ lb.} \quad (1)$$

Taking moments about the point O at the front, by the principle of moments

$$168\ R_1 + 20\ R_2 = (154 \times 2480) + (82 \times 200) + (47 \times 300) + (8 \times 200) = 414{,}100 \text{ lb.-in.} \quad (2)$$

Thus we have two simultaneous equations, (1) and (2) Solving equation (1) for R_1 gives

$$R_1 = 3180 - R_2$$

Substituting this value for R_1 in equation (2), we write

$$168\ (3180 - R_2) + 20\ R_2 = 414{,}100 \text{ lb.-in.}$$

Then

$$534{,}240 - 148\ R_2 = 414{,}100 \text{ and } R_2 = 812.3 \text{ lb.}$$

In a similar manner R_1 equals 2367.7 lb. or R_2 can be deducted from the total weight to determine R_1. Since we have in this example two half-elliptic springs supporting each side-member, with the axles located centrally between the spring-eyes, the reaction at each spring-eye is taken at one-half the values derived for R_1 and R_2 respectively, or 1183.85 lb. at each rear spring-eye and 406.15 lb. at each front spring-eye, as shown in Fig. 1.

The next procedure is to determine the bending moments at various points along the frame. To make the diagram fairly accurate, the bending moments are determined at each 6 in. of the entire length. The 2-ton load and the body weight are considered as being evenly distributed over the 124-in. length and so 2480 ÷ 124 = 20 lb. per in. In practice, the frame weight per inch of length can also be included to insure greater accuracy; also other concentrated weights that may be suspended from the frame. The bending moment M at any vertical section of a beam equals the algebraic sum of all the moments of the external forces about that section, acting either to the right or to the left of the section. Table 1 gives all the values so calculated, but the bending moments are worked out for a few points to clarify the method for those who are not familiar with it.

TABLE 1—BENDING MOMENTS FOR EACH 6 IN. OF LENGTH IN FIG. 1

Distance from Left End of Frame, in.	Bending Moment, lb-in.	Distance from Left End of Frame, in.	Bending Moment, lb-in.
6	— 360.0	114	26,308.0
12	— 1,440.0	120	26,474.0
18	— 3,240.0	126	26,185.0
24	— 5,760.0	132	25,287.0
30	— 1,897.0	138	23,813.0
36	1,246.0	144	21,940.0
42	3,669.0	150	20,066.0
48	5,372.0	156	18,192.0
54	6,356.0	162	16,318.0
60	6,619.0	168	14,444.0
66	6,162.0	174	11,071.0
72	4,985.0	180	9,021.0
78	10,191.0	186	7,785.0
84	14,677.0	192	6,548.0
90	18,443.0	198	5,310.7
96	21,490.0	204	4,073.8
102	23,816.0	210	2,436.9
108	25,422.0	216	0.0

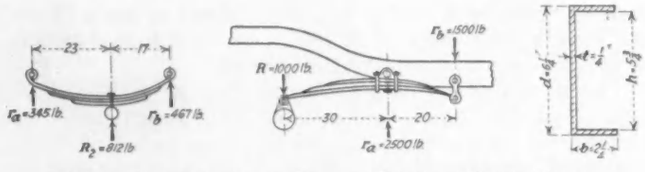


FIG. 2—DISTRIBUTION OF LOAD IN VARIOUS TRUCK PARTS From Left to Right These Are a Front Spring, a Half-Elliptic Cantilever Spring and a Frame Channel

The moments which would tend to produce clockwise rotation on the left of the section are taken as being positive, and those tending to produce counter-clockwise rotation as being negative. The reverse of this is true when the moments on the right of the section are considered. Beginning at the left and up to the first spring reaction R_1, the moments can be calculated from the formula for uniformly loaded cantilever beams.

$$M = \tfrac{1}{2} LW$$

where

M = the bending moment
L = the length of the cantilever beam up to the point at which the bending moment is to be determined
W = the total weight on the cantilever beam up to that point

Over the first spring-eye reaction r, we have

$$M = -\tfrac{1}{2}\ L\ W = -[\tfrac{1}{2} \times 24 \times (24 \times 20)] = -5760 \text{ lb-in.}$$

Beyond the 24-in. point, to the right, the moments due to the reactions must be considered. At 42 in. from the left we have, in addition to the negative moment, the positive moment due to the spring-eye reaction r_1. Thus,

$$M = -[\tfrac{1}{2} \times 42 \times (42 \times 20)] + 18r_1 = 3669 \text{ lb-in.}$$

At 84 in. from the left we have

$$M = -[\tfrac{1}{2} \times 84 \times (84 \times 20)] + 60r_1 + 12r_1 = 14{,}677 \text{ lb-in.}$$

It is in this manner that all of the figures in Table 1 were obtained. From these values the bending moment diagram is drawn, as shown by the full-line curve in Fig. 1. The vertical or ordinate values are laid off to some convenient scale. Each space in Fig. 1 represents 1000 lb-in. The bending moment at every point of the frame is evident from a glance at this curve. The ordinates above the base line AA represent the positive moments; those below represent the negative values.

When the axle is not at the center of the spring, that is, with offset springs such as are used frequently with front suspension, moments must be calculated to ascertain the reactions between the spring-eyes and the frame. Let us suppose the case of a front spring eccentrated as shown at the left of Fig. 2, in which the axle is 17 in. to the rear of the front spring-eye. By taking moments about r_a we have

$$40r_b = 23R_2$$

so that

$$r_b = (23 \times 812) \div 40 = 467 \text{ lb.}$$

and

$$r_a = 345 \text{ lb.}$$

When calculating the stresses in a frame, the reactions must be established carefully to obtain accurate results.

With half-elliptic cantilever springs, the reactions at the frame supports may be considerably higher than the axle reaction. Taking the example shown in the central drawing of Fig. 2, where this type of spring is attached to the frame at a point 30 in. from the axle and the other end is anchored to the frame 20 in. from the spring-bolt, assuming that the axle reaction R is 1000 lb., moments are taken about the front end r_b to find the reaction at r_a. Thus,

$$50 \times 1000 = 20r_a$$

and

$$r_a = 50{,}000 \div 20 = 2500 \text{ lb.}$$

Since r_b will act downward like an extra load on the frame

$$r_b = (30 \times 2500) \div 50 = 1500 \text{ lb.}$$

Thus it is evident that the type of spring employed has an important bearing on frame stresses.

Shearing Forces

In a frame channel, only the vertical shearing stresses need be considered. The magnitude of the shearing force at any vertical section of the frame is the algebraic sum of the shearing forces acting on either side of that section.

The shearing stresses at one point are worked out to show how the values were obtained from which the shearing-force diagram, shown by the dotted lines in Fig. 1, is drawn. At the front spring-eye of the rear spring, 72 in. from the rear of the frame, the total load tending to cause a negative shear of the section is $72 \times 20 = -1440$ lb. At the left of the section we have the positive shear of 1183.85 lb., the first reaction, and $-1440.00 + 1183.85 = -256.15$ lb., and at the right of the section the shear is $-1440.00 + 1183.85 + 1183.35 = 927.70$ lb.; hence, at this section the shearing stress changes from negative to positive. Attention is called to the fact that at the maximum bending moments the shear is always zero. The stresses in the frame metal can be determined from the bending-moment diagram when the dimensions of the channel are known. The stress in any layer of a beam varies directly as the distance from the neutral axis, the maximum fiber stress being in the upper and lower flanges of the channel. Knowing the moment of resistance or the bending moment M at any section of the channel, the maximum stress can be determined from the well-known formula

$$M = SZ \text{ or, } S = M/Z$$

where

S = the maximum fiber-stress per square inch in the section

Z = the section modulus

Let us suppose that the channel used in this frame is of the section and dimensions shown in the drawing at the right of Fig. 2. The section modulus of a channel is given in most engineering handbooks and, in reference to the drawing at the right of Fig. 2,

$$Z = [bd^3 - h^3(b - t)] \div 6d$$

Substituting the dimensional values given in the diagram at the right of Fig. 2 and solving this equation, $Z = 4.5$.

The maximum bending-moment is at a point about 120 in. from the left end of the frame as shown by the diagram. Here $M = 26{,}474$ lb.-in. and the maximum stress is

$$S = M/Z = 26{,}474 \div 4.5 = 5900 \text{ lb. approximately}$$

However, it must be remembered that this stress of 5900 lb. in the outer fiber is induced when the load is static on the frame as shown. The springs sometimes will be deflected to about twice their static deflection due to impact under running conditions, or as much as their clearance will allow and, since the deflection in a spring is proportional to the load, the load on the frame must be assumed to be double the normal load shown. Hence, the bending moment, and consequently the maximum stress in the frame, are at least double the amount that has been stated.

The stress is considerably more when the frame hits the axle, as it does sometimes, and the load on the frame arising from the torque-arm or torque-tube when applying the brakes may alter the stress distribution in the side-members very materially. Taking the stress at twice the amount that has been calculated gives a maximum stress of 11,800 lb. per sq. in. If the ultimate strength of the material is 60,000 lb. per sq. in., the factor of safety is approximately $60{,}000 \div 11{,}800 = 5.1$. This is none too much when the overloads to which a truck is subjected are considered, and when the fact that the load on the frame due to the torque, when the truck is being stopped with the wheels locked, was not taken into account. In practice this load should be considered.

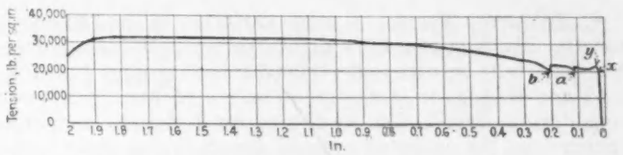


Fig. 3—Chart Showing the Results of a Laboratory Test on a ⅞-In. Wrought-Iron Sample

By studying the bending-moment diagram in Fig. 1 one can see at a glance where the frame can be lightened without sacrificing strength. The shearing stress is greatest near the spring-shackles; the maximum is less than 1000 lb. per sq. in. in the example given. The ultimate shearing strength of this quality of steel is about 50,000 lb. per sq. in., hence the section given as an example is ample. There is more danger from a crumpling of the web than from a shearing of the metal.

Laboratory Tests of Materials

We have made laboratory tests of the ultimate strength, elastic limit, yield-point, elongation and reduction in area on an Olsen testing machine. This is provided with an attachment that automatically draws a curve showing the elastic limit, yield-point, elongation and ultimate strength, such as is shown in Fig. 3.

A wrought-iron sample ⅞ in. in diameter and having an area of 0.6013 sq. in. was tested. Its tensile strength was 32,000 lb., approximately 53,000 lb. per sq. in. Its elastic limit, shown at x, is 20,000 lb., approximately 33,200 lb. per sq. in. The yield-point, shown at y, is 22,000 lb., about 36,600 lb. per sq. in. and it is evident that at y the deformation or elongation begins to increase rapidly. The machine was stopped for a few seconds at a and at b. In following the continuation of the curve the large increase in length for a very small increase in load should be noticed, until rupture finally occurs at a load of 32,000 lb. or 53,000 lb. per sq. in.

It will be noticed that just before rupture occurred the increase in length was 2 in. and, since the sample originally was 8 in. long, the elongation in 8 in. was 25 per cent. Test samples of round stock are made ordinarily only 2 in. long; data on test samples are given in the S. A. E. Handbook.[*]

The diameter of the sample is 0.572 in. at the place of rupture, or 0.257 sq. in.; hence the reduction in area is $(0.6013 - 0.257) \div 0.6013 = 57$ per cent approximately.

Full details of the test for the modulus of elasticity are given in Chapter XVII of my textbook on Motor Vehicle Engineering, but this test is not sufficiently accurate to show the exact deformation or elongation, within the elastic limit of the material; but we can estimate it to be about 0.01000 in., or 0.00125 per in. of length, when the load is 20,000 or 33,200 lb. per sq. in. Therefore the modulus of elasticity, E, is as follows:

$$E = \text{Stress/Strain} = 33{,}200/0.00125 = 26{,}500{,}000 \text{ lb. per sq. in.}$$

THE DISCUSSION

Adrian Van Muffling: What is considered the usual factor of safety?

[*] See S. A. E. Handbook, vol. 1, p. D4.

E. FAVARY: There is a great variation in the factor of safety. My idea of a satisfactory factor is to take double the load, take into consideration all the stresses for this load and then allow a factor of safety of five. I advise considering double the load because I figure that the springs can be deflected only to about double their normal static deflection. Of course, this does not always hold good, but I have assumed this as the maximum load. If the frame is either too rigid or if too flexible, it is not satisfactory. Frames now are made more rigid than formerly.

C. M. BILLINGS: Is not most of the breakage resulting from the stresses imposed due to the frame being supported on four rather than three points? It seems wrong in principle to subject the frame to stresses caused by inequalities of the roads. Would not a three-point suspension such as is used on tractors be better?

Mr. FAVARY: A frame gives and if there is an excessive strain in a certain part of it or if the frame is longer, it will cause a greater bending moment and a greater fiber stress in the channel. I cannot see how three-point suspension can reduce the fiber stress due to a given load.

Mr. BILLINGS: In the case of an ordinary four-wheel truck, with a heavy load on its platform, the side-rail member is subjected to torsion as well as the bending stress due to the superimposed load. It is weaker than when subjected to the ordinary bending load?

Mr. FAVARY: Yes, but I question whether this torsion is sufficient to be of importance, for a very small torsion in one side-member will permit the other to rise considerably. Do not forget that there is some play in the spring-shackles. We know very well that we can take a piece of frame channel and twist it somewhat without damaging it. I think it is very rare for frames to give way as a result of torsion.

Mr. BILLINGS: One of our reasons for concluding that frame distortion causes much trouble is the vertical displacement of the rear doors of a motor-truck body. This up-and-down motion is particularly noticeable on a large van body. It has always been a problem to keep the bolts tight on the chassis and the body.

Mr. FAVARY: No doubt the frame does distort and a more rigid frame distorts the body less but I do not believe the ordinary distortion exceeds the elastic limit of the metal. A piece of channel iron can be twisted considerably.

Mr. BILLINGS: Not indefinitely.

N. G. BERGENHOLTZ: That is in the case of a rigid frame. I agree that there would be a large amount of stress due to the four-point-suspension semi-flexible frame. I have found that if one wheel is raised 10 in. above the ground, which is a fairly good height, the side-member does not twist over 1/16 in. I think the stress affects the cross-members more than the side-rail, because they seem to be twisted more. There does not seem to be any distortion in the side-member.

Mr. DEAN: Does not the stress have a tendency to loosen the rivets?

Mr. FAVARY: No.

FRAME RIGIDITY

Mr. DEAN: Does not the twisting of the frame wear the shackle-pins and bushings?

Mr. FAVARY: Yes, perhaps, but it seems more desirable to take the wear on them than on some of the other units.

Mr. DEAN: Can it not be eliminated by making the frame absolutely rigid?

Mr. FAVARY: There is no such thing as absolute rigidity in mechanics.

Mr. DEAN: I mean as nearly rigid as is possible. When an engine is carried in the frame without any subframe, are we not liable to distort the engine-base?

Mr. FAVARY: We often rely in such cases on the engine-base for added rigidity. At other times builders provide a certain swivel action to permit the engine to adapt itself to the frame when there are slight distortions.

Mr. DEAN: The Pierce-Arrow truck has a flexible frame; do you think there is any wear on the shackle-pins?

Mr. FAVARY: Yes.

Mr. DEAN: Is it due to the twisting of the frame?

Mr. FAVARY: I am not prepared to say. We learn in the laboratory that one conclusion is not final; when we think we have solved a problem or that we know the reason of some new effect we make confirmatory tests. We must suspend judgment until the circumstantial testimony is such that it can be relied upon. We should never judge finally by one or two cases.

Mr. DEAN: Is it not a fact that, due to the twisting of the frame, the spring-clips become loose?

Mr. FAVARY: In a measure probably.

Mr. DEAN: Why not adopt a more rigid frame on the order of the three-point suspension and eliminate that difficulty? Would there not be less wear on all parts?

Mr. FAVARY: Practice has shown that where too rigid a frame is used breakages often occur which do not take place in a more flexible frame. In case of impact the stresses are very much more severe in a relatively rigid body.

Mr. DEAN: Why not make the spring suspension flexible instead of the frame itself?

Mr. FAVARY: A number of different devices have been tried to obtain this result but it would be presumptuous on my part to answer the question offhand.

Mr. DEAN: In a long experience I have found that the spring-clips become decidedly loose on all makes of truck; but on the Pierce-Arrow the spring-clips and the shackle-pins very seldom become loose. The flexible frame distorts the body and it is impossible to keep it tight. Why distort the body to make the frame flexible, and still have a flexible suspension?

Mr. BERGENHOLTZ: I think that there is more wear on the pins with a rigid frame. With the flexible frame the springs are not distorted so much in going over obstructions. Regarding the distortion of the semi-flexible frame, another thing is that there is a long lever-arm up to the front end of the truck and, if one of the front wheels is raised about 10 in., it will be found that one side of the frame rises only about 2½ in. above the other. In other words, the spring action absorbs much of the up-and-down movement of the wheels and, because the frame is flexible, it tends to keep the springs more in line and eliminates the side-weave. Another point is that the springs must be rigidly fastened to the axle in the present form of construction, which is practically universal, to take care of any side-movement. If the spring were flexibly mounted on the axle, there would be nothing to prevent the side-movement of the whole frame. We can use a rigid frame and save the body at the expense of the frame, or a flexible frame, which will last longer, and put a new body on it from time to time.

W. C. GREENE: Let us take a sane view of the matter of torsional stress, since that stress is distributed over rather wide limits. If we were dealing in short distances, we would have something to worry about, but we

have very little actual bending-moment per unit of length.

ENGINE MOUNTING IN THE FRAME

D. LANDAU: The Mercedes has a four-point suspension crankcase and depends on that to keep the frame side-members the proper distance apart. With too flexible or too rigid frames the strain on the mechanism is of considerable importance, so far as the frame is concerned; that is, if the frame is distorted, there is a tendency to jam the units of the mechanism.

MR. BERGENHOLTZ: This is a more important point, I think, than the distortion of the frame. We have a three-point engine suspension. The front point is rigidly fastened, as regards sidewise movement in the frame, and the two rear supports are rigidly fastened. We have a triangle that does not allow much flexibility so far as movement of the side-members is concerned.

I understand that there have been a considerable number of breakages lately of flywheel housing arms, at the point where they are supported. I suppose that this is due to their being too light. With a flexible frame a flexible rear engine-support is necessary, or the crankcase must be stiffened to take care of the strain imposed by the distortion of the frame. I think we must work with the flexibility of the units, to keep the frame flexible or semi-flexible.

JOSEPH A. ANGLADA: In the past few years we have been gradually increasing the depth of the frames; last year this was done very decidedly. A number of car builders have increased the depth to 6, 8 and 8½ in. They are using better material, and are making the frames rigid. There was an idea that the flexible frame has the advantage of making the car ride more easily. It does not. We have better riding cars now with the stiff frames than we had with the flexible frames, because we know how to make better springs. In addition, when we make a body and put it on the frame, there is no difficulty about opening the doors. As to the factor of safety, I had occasion to make investigations of broken frames and, in each case where a frame was broken, I found that the factor of safety was less than 10, with a static load.

MR. BILLINGS: In the development of a three-point-suspension truck and in figuring the stresses on the majority of the well-known trucks, we have found that they were pretty well up to the safety limit according to the way we analyzed them, which we believe was the correct way. The frame on the three-point-suspension truck was made of 8-in. standard I-beams, and was perfectly rigid. There were no spring-shackles, so there was no trouble with shackle wear.

MR. FAVARY: When a frame is made as heavy as that, do you not carry too much dead-weight all the time?

MR. BILLINGS: The weight of the chassis complete, with gasoline, oil and water, is 8130 lb. We have repeatedly obtained an average of 6 miles per gal. of gasoline.

W. A. MCKINLEY:—The method of computing stresses for an automobile is very simple after certain assumptions and allowances are made. An overload of 50 per cent is generally allowed in the case of truck frames, the load being considered as distributed equally over the platform. Assuming a tensile-strength of 60,000 lb. for steel and a factor of safety of 10, the stresses can be computed either algebraically or by the string polygon method, the former being the more accurate. It must be assumed first that the side is a beam supported at two points; this assumption is not exact, but it approximates the actual condition closely enough to be used.

The first step after laying out a proposed frame is to plot the bending-moments at intervals of the frame length, together with the moment of resistance. This will show immediately where the proposed frame is weakest and where the sections must be increased. Obviously, it will show also where the frame can be lightened considerably. This information, together with considerations affecting economical manufacture, will enable the designer to distribute the metal properly along the rail so that no excess dead-weight will be carried by the chassis. There seems to be a wide diversity of opinion as to how heavy truck frames should be made. I heartily endorse Mr. Favary's view as to the need for a greater amount of standardization data for truck frames.

Stiffness is a quality that engineers demand increasingly. We have seen the general trend of design change from 3½ and 4-in. section rails to 7 and 8-in. rails on present-day construction. This was done not only to increase the strength or the resisting moment, but also to increase the stiffness. Whatever arguments are advanced for flexible frames, it must be remembered that other more important units are subjected to severe strains when a frame is allowed to flex. For this reason alloy steels are not in wider favor. Although it is very easy to design an alloy steel section that is smaller in size and of lighter stock and to obtain the same resisting moment as when the larger carbon-steel section is used, the stiffness of the section is proportional to the modulus of elasticity of the material and this is the same for both carbon and alloy steels. Consequently, lightening the section means a sacrifice in stiffness, a fact which cannot be ignored.

C. L. CLARK:—The frame is an important unit in truck and automobile construction, and yet it is the least standardized. As Mr. Favary says, there is a wide difference in the stress in the frame side-members of trucks of various makes. This indicates either that the manufacturer has not accepted a certain factor of safety as standard, or that the stresses have not been checked. The same condition exists among automobile builders. The result is that trouble with breakage has occurred. Often, the first thought of the engineer is that the material is at fault; yet in the majority of instances a careful analysis of stresses indicates a weakness in design. On the other hand, many truck frames are too heavy and a saving could be effected in both material and weight.

It is important in designing a frame to prepare a loading diagram from which the bending-moment diagram or curve can be drawn and the static stresses determined throughout the length of the side-member. It is not sufficient to consider the frame as being satisfactory after this investigation, because failure may develop on account of the use of an insufficient number of cross-members, lack of bracing to hold the frame square, or an improper mounting of units.

Several types of truck frame are in use. The side-members are straight and of uniform depth, tapered at one or both ends, or formed with a nose-bend at the front end for the front spring-horn. An offset is used frequently for the light and medium-weight trucks; it is located somewhat to the rear of the front wheel to provide a shorter turning-radius. The flanges are tapered usually, although the practice in this respect is not uniform. Reference to Mr. Favary's bending-moment diagram indicates the feasibility of tapering both the front and the rear ends of the frame side-member. It also discloses that the center section, that is, the section of the side-member between the front-spring rear-bracket

and the rear-spring front-bracket, serves as a convenient basis for checking the suitability of a frame for a truck. For a given truck, assuming that a section modulus for the section at the point of maximum moment is 4.5, then for another truck having nearly the same loading diagram and wheelbase an approximately equivalent section would be required. We are thus enabled to adopt certain standard values for the section modulus of side-members for trucks of different capacity, making proper allowance for vibrations in wheelbase and distribution of load. This information is of considerable value as a guide in determining the suitability of a frame for a truck of known capacity.

In general, the same factors relating to the strength of truck frames apply to automobile frames; however, more careful consideration is given to weight. The tendency is to make the center section of the side-member relatively more rigid, on account of the effect of deflection upon the body. For spring-brackets, experience points to the desirability of keeping shackle-pins below the lower flange of the rail when possible; otherwise a deeper rail-section must be used at the shackle. In any event the strength of the side-rail member must be checked carefully at these points, because frame breakage will develop if a sufficient factor of safety is not maintained. Another possible source of trouble lies in the mounting at the rear engine-supports. Some car-builders prefer to carry the rear end of the engine on brackets projecting out from the side-members. This mounting, unless of such design as to comprise in effect a rigid cross-member, sets up a torsional stress in the side-member, in addition to the vertical load due to the weight of the unit supported. The torsional load is augmented very considerably by road shocks and requires the use of a stronger side-member than would be necessary with the rigid-cross-member type of support. I have traced the failure of a number of frames to the method of mounting at the rear engine-supports.

Too much stress cannot be placed on the fact that, to avoid breakage, the engineer should make sure that there are no weak points in the frame design. Having determined this, he is then in a position to increase the strength of the members if greater rigidity is desired. This procedure will discount to a considerable extent the development of possible weakness in frames after the cars have been subjected to use.

ENGINEERING SUCCESS

THE most important elements that contribute to the success of an engineer can be included under five heads: (*a*) technical ability, (*b*) breadth of knowledge, (*c*) initiative, (*d*) executive ability and (*e*) ability to write and speak clearly and forcefully. Apparently, in the past at least, the chief aim of the engineer has been to perfect himself in technical details. Many, if not most, engineering instructors have been impressed with the magnitude of the field of engineering knowledge and have given their best effort to imparting to their students what they believed to be the technical information needed in their future work. Therefore, the chief aim of the engineering student has been naturally, and almost universally, to acquire facts about his chosen profession. The mere accumulation of technical information has little or no educational value. The power to observe closely, reason correctly and make clear statements is of vastly greater importance than any amount of technical information; technical details without these qualities are absolutely useless. Technical details speedily get out of date; but these qualities are never out of date, and are always valuable whatever a man does.

The student should seek continually to get the maximum intellectual development as he acquires technical facts. He should seek to understand the relations between the facts and fundamental principles. Inquire the reasons for the particular practice and determine whether it is general or due to some limiting condition of time or cost. He should regard his study as a test of how quickly and certainly he can acquire the significant facts from the printed page. The development of the mental powers alone confers that which masters all it touches, can adapt old forms to new uses or create new and better means of reaching old ends; and without this power the engineer cannot hope to practice his chosen profession for any very great length of time with any considerable chance of success.

The engineer should understand at least some of the fundamentals of economic problems, social conditions, political questions, legislative action and know something of the subtle relations of labor and capital, the factors affecting international trade and other questions that form the subject of the thought and the conversation of his business associates and other professional men. If the engineer is found seriously lacking in knowledge of these subjects, the layman considers him an ignorant man.

Without the power of initiative, the power of self-direction, no one can hope to be trusted with much responsibility. Men who are at the head of large enterprises and carry great responsibilities are always looking for those who have initiative; and not infrequently they choose the uneducated man, or perhaps I should say the unschooled man who has the power of initiative, in preference to the college-trained man who does not have it.

A good executive is a man of initiative and self-reliance, who understands other men and knows how to secure their hearty cooperation. This requires tact, patience, perseverance, courage, ability to judge men, knowledge of character and understanding of motives. The engineer does not usually give heed to these matters, this is at least one reason why he is seldom advanced to the higher administrative positions. Administrative officials are always looking for men who will help them to carry their load, and invariably the pay is comparatively high because such men are relatively scarce. Many high-priced positions in the engineering field are held by non-engineers because no engineer could be found with the necessary executive ability.

The engineer, in college, and also after graduation, has been so intent upon perfecting himself in technical details that he has neglected the means of communicating his thoughts by writing or speaking to his fellow men. The engineer, if he is to attain to any considerable prominence or influence in his community, must do business with other men, explain plans, write letters, prepare contracts, give testimony in court and write reports; unless he has acquired the ability to express his thoughts in clear and forceful English he cannot influence others to accept his views or convince them that he is an intelligent or educated man. Other men are not able to judge him by his technical attainments, but do judge him by his ability in writing and speaking. Unless he uses clear and forceful language, others are likely to assume that he is an ignorant man, and consequently his professional standing suffers and his influence as a citizen is weakened.—From an address by I. O. Baker before the Purdue University Student Chapter of the American Society of Civil Engineers.

Anti-Freezing Solutions

IN connection with the Farm Power Session of the Society held at Columbus, Ohio, Feb. 10, 1921, a preliminary report of the Committee on Anti-Freezing Solutions was made by O. B. Zimmerman, of the engineering staff of the International Harvester Co., Chicago. The report as presented is given below.

PRELIMINARY REPORT

This Committee presents a report of progress at this time on the status of anti-freezing solutions, which is of recurring interest yearly. Relatively little constructive work has been done on this question other than that of designing a cooling system to operate with water as the cooling medium. The function of the cooling system is that of taking care of a quantity of heat units liberated by combustion greater on the average than is transformed into mechanical power and nearly equal to that ejected with the exhaust. It seems worth while, therefore, to give a more detailed study to the question of the media possible of use.

Satisfactory lubrication of pistons, piston-rings and valves is dependent very largely upon the successful removal of approximately 30 per cent of the heat units from the gasoline and kerosene fuels used and dissipated during the working cycle of today. Again, in the necessity of having to meet a wide range of normal seasonable temperatures, as well as extremes of winter and summer, we find that we have a real research problem to solve. Even before the development of internal-combustion engines efforts were made to overcome the deficiencies of water as a cooling medium, but with the coming into use of internal-combustion engines the evil or aggravating results produced by the sedimentary deposition of soluble substances, as well as those mechanically carried into the cooling system by land waters, have caused much trouble, especially in farm tractors, the water supplied to which is too often carelessly or of necessity poorly chosen and in which the deposition is more extensive than in automobiles. This is owing to the higher average temperature, and the accompanying danger of overheating in spots even when large free passages are provided and no blind pockets are present. Expensive repairs due to jacket freezing, radiator leaks, frozen pumps and the like excited a series of attempts to solve this difficulty by mechanical means. Examples are found in air-cooling, mechanical devices to prevent damage by expanding ice, devices of various kinds to control low temperatures by the use of heat and devices providing for the automatic withdrawal into storage of the fluid when the engine is inoperative. Also there have been numerous efforts to solve the problem by the use of mixtures of salts or other chemicals in solution with water to lower the freezing-point of the mixture; such examples as calcium chloride, common salt, glycerine, alcohol and glycols can be mentioned. Lastly, there is the series of mineral oils that maintain fluidity or resist both high and low temperatures within the reasonable demands of out-of-doors engine practice. It is the endeavor of the Committee to review these last two groups with the idea that whatever the final conclusions may be, the state of the art should be defined. Further detailed study and research can then be undertaken in the same thorough manner as that in which the subjects of lubricants and fuels are treated.

That the precautions against freezing occasion the greatest amount of anxiety in winter and result in the largest percentage of damage to the machine if not closely guarded against, is freely acknowledged; hence, it is our duty to overcome this difficulty. Taking the ideal requirements of a cooling medium as a basis to work from, we can enumerate these requirements briefly as follows:

(1) The cooling medium must be cheap and easily obtainable
(2) It must be reasonably non-corrosive, and not cause electrolytic action
(3) It should have a boiling-point not too high above that of water, such as 250 deg. fahr.; it should not freeze much above minus 20 deg. cent. (— 4 deg. fahr.) or about zero fahr.
(4) It must be a mobile fluid or have a low viscosity through this range
(5) The fire hazard should be at a minimum
(6) The specific heat should be as nearly that of water as is practicable, and the heat conductivity should be as high as possible
(7) Low expansibility is desirable
(8) It must withstand the continuous heat of an engine without undue decomposition or molecular change
(9) If practicable, it should be a year-around fluid or one that is readily capable of replacing water in the winter months
(10) It seems feasible to consider groups of requirements to fit not only needs but also personal factors, where expense and care do not control, as compared to tractor requirements

With these requirements in mind we shall scan the information furnished by a review of patent office data, supplemented by the experience of different operators and firms. A review of the subject of anti-freeze solutions has already appeared in THE JOURNAL,[1] this being a preliminary statement of the Bureau of Standards, which is investigating the subject. Since that article had in view, primarily, the requirements of automobiles and the report of this Committee covers trucks and tractors as well, a duplication of certain conclusions and data is warranted.

It must be acknowledged freely that the use of salts like calcium chloride, in the hope that the average user would make his own solution, is out of the question; the average user's knowledge of the purity of substances being exceedingly meager, it seems sensible to leave his choice of solutions along this line open only to the selection of such reliable articles as may be available. The consensus of opinion is, however, that this method of using salts for preventing freezing is dangerous and undesirable, because electrolytic action is almost certain to follow; and that it should be discouraged at present.

In the use of alcohols we undoubtedly find almost a unanimous opinion in favor of this method of reducing freezing difficulties, although the free boiling-off of the alcohol leaves constant uncertainty as to the nature of the solution and its cold-resisting qualities. The tables formerly given in the S.A.E. HANDBOOK are satisfactory, but it appears desirable to add thereto the tables given by the Bureau of Standards in its preliminary report covering the use of alcohols and glycerine. Pure amyl alco-

[1] See THE JOURNAL, October, 1918, p. 285.

hol, in addition to methyl and ethyl alcohol, has had a thorough trial and is in a fair way to be recommended. This alcohol is a variety of amyl hydrate obtained by the fermentation of potatoes, and should be produced cheaply and easily. The mixture of 1 part of amyl alcohol with 39 parts of water forms a liquid of 0.998 specific gravity. This liquid freezes at — 20 deg. fahr. and has a boiling-point of 264 deg. fahr.; hence, unlike ethyl and methyl alcohol, it has the advantage of not boiling off ahead of the water. Its specific heat is given as 1.6.

In the review of patents we find one covering the use of glycols of the 1.2 type, which in approximate proportions of 60 to 65 per cent of water and 40 to 35 per cent of glycols, make a very satisfactory cooling medium. A good discussion of this subject is given in United States Patent No. 1,213,368. Other United States patents to review are Nos. 1,102,777, 1,082,528, 1,282,249 and 1,319,178.

There remains to discuss the group of mineral oils and their use as a cooling anti-freezing fluid. Numerous opinions have been given against the use of oils but in each case, so far as we are aware, the opinion has been based on guesswork rather than experience. The fact remains that, in the development of heavy tractors from 1904 to date, successful cooling has been accomplished and persists with the use of heavy oils covering all seasons of the year. The Committee has numerous records of trucks and several makes of automobile having used kerosene without difficulty throughout the winter season. While the heavy oils require certain special design features to accomplish complete success, on the whole the difficulties noted are not serious. Technical data covering the characteristics of these mineral oils for this purpose are not at hand and efforts are being made to secure them for the final report. Such information as relates to heat conductivity and specific heats, speed of heat transfer from medium to metal and metal to air, and the like will require more research. The rates of diffusion and absorption have not been obtained. The difficulties reported or noted when using kerosene cover the following:

Leakage The pumps normally require better care than with water to minimize the danger from fire and undesirable odors

Destruction of Hose The life of hose is reported to be from three months to two years according to quality. This is a minor expense compared with the convenience, in the opinon of several who have used kerosene

Odors For use in the better quality of cars, this feature is worthy of consideration. With tractors and trucks, odor is not so important a determining factor

Foaming The presence of water in the system along with the oil is very undesirable; hence, careful draining is an important preliminary to replacement with oil. Usually, operators report little trouble after the first elimination

Short-Circuiting This difficulty seems noticeable at the start when the outfit is still cold, because of congealing when the heavy oils are used in extremely cold weather. This difficulty is overcome readily by the addition of a small percentage of kerosene

Expansion Provision must be made for the greater expansion of oil with heat; when oil is substituted for water

Viscosity Free or larger passages are more necessary than with water

Low Specific Heat This runs about one-half that of water; hence the necessity of giving more speed to the circulation

Fire Hazard An increase in the fire hazard has been reported by a number of representatives, but so far no record is at hand as to actual destruction from this cause

The general conclusions at this time are that the subject deserves special and more complete study, particularly from the standpoint of the truck and the tractor, as these machines are subjected more completely to intense heat and cold and must be ready to do their duty at all times.

The preliminary report on this subject of the Bureau of Standards, dated Jan. 5, 1920, is appended.

Report of the Bureau of Standards

The question of anti-freezing solutions for automobile radiators has been brought very forcefully to the attention of users of motor vehicles this winter, and many requests for information regarding their use have been received at the Bureau of Standards. An investigation was undertaken by the Bureau to establish the value of these compounds and sufficient data have been obtained recently to justify a preliminary statement. The tests were made on the metals, such as brass or copper and solder, that are used in radiator construction and in the same combinations that are employed for this purpose. This was necessary to investigate the electrolytic action that is largely responsible for radiator corrosion; tests made without regard to electrolysis are practically worthless. This work will be continued; tests equivalent to service conditions will be made and a more comprehensive report given at a later date.

The ideal anti-freezing compound is one that will prevent freezing of the radiator liquid without injuring either the engine or the radiator, that will not lose its non-freezing properties after continued use and that does not change materially the boiling-point of water when dissolved in it. There are two general types of these compounds; one a solution in water of alcohol or glycerine, or a mixture of the latter two, the other a solution in water of calcium chloride or the dry salt itself that sometimes contains small amounts of other substances such as salt, sal ammoniac, sugar or syrup. Kerosene and similar oils, without admixture, are sometimes used. Kerosene has a lower freezing-point and a higher boiling-point than water, but the inflammability of its vapor makes it dangerous to use, and its high and uncertain boiling-point might lead to the serious overheating of the engine, or even to the melting of the solder in the radiator. It has a marked solvent action on rubber parts. These facts seem to indicate clearly that this material should not be used. The alcohol-water type is the most common and is not generally sold under any trade name, but recently there have appeared on the market a number of anti-freezing compounds of the calcium-chloride type. These compounds are sold under a variety of names and startling claims are made for their effectiveness and lack of injurious effects. The effectiveness of all properly prepared compounds, that is, their ability to prevent freezing, needs no discussion. The injurious effects, however, cannot safely be disregarded.

The alcohol solutions do not exert a greater corrosive action than water alone. This can be predicted from theoretical considerations and is well established in practice. However, wood alcohol sometimes contains free acetic acid, which is objectionable. For this reason, wool alcohol should not be used unless it is known to be free from acid. The calcium-chloride compounds exert a greater corrosive action than water on the engine jacket, on the

solder in the radiator and on the aluminum that is sometimes used in manifolds, pumps and headers. The effect on engine jackets can be neglected since these are generally sufficiently heavy to permit considerable corrosion without their being weakened. The effect on soldered joints may be serious, since tests made at the Bureau of Standards have shown the complete removal of solder from copper and brass when immersed in a hot 20-per cent calcium-chloride solution for 4 days. A number of such tests were made and there was always a more rapid corrosion or eating away of solder in these anti-freezing compounds than in water. Calcium-chloride solutions corrode aluminum very rapidly. The effect is variable, depending on the kind of aluminum used; blisters appear on ordinary rolled sheet-aluminum and, as these break, the metal separates into scales or plates of corroded aluminum that open up like the leaves of a book; cast aluminum, especially the copper alloys, shows very decided pitting and etching. These tests prove that the corrosive action will be very serious and it is difficult to reconcile these results with the current statement that the effect of calcium-chloride solutions on aluminum is not very serious. Another troublesome effect of calcium-chloride solutions is experienced if small leaks occur in the radiator, the water-jackets or their connections, and the solution comes in contact with the spark-plugs and ignition wires. In some cases the drops of the solution may be carried back on the engine in a more or less atomized state, assisted by the fan when running. The salt deposited when the water evaporates is very difficult to remove and, when it cools, it absorbs water and becomes a good electrical conductor, short-circuiting the spark-plugs and sometimes making it impossible to start the engine. The difficulty may disappear when the engine is heated up. There are also certain conditions in the manufacture of calcium chloride that may result in a compound that will deposit large crystals in the radiator as the solution cools; this may prevent effective circulation.

Regardless of these objections, reports have been received to the effect that calcium-chloride solutions have been used a number of years in the same radiator without producing apparent corrosion. Nevertheless, such solutions cannot be recommended as safe, and they should not be used if there is any aluminum in the cooling system. The chief advantage of calcium-chloride compounds is that they are not volatile. The solutions can be kept practically uniform by adding water from time to time. Unfortunately, this is not true with the alcohol solutions, because the alcohol continually boils out and must be replaced frequently to maintain the proper proportion of alcohol. Glycerine is frequently substituted for part of the alcohol to reduce evaporation, but when glycerine is used the rubber connections may be affected somewhat seriously, depending on the quality of the rubber. The most practical method to maintain the proper quantity of alcohol in the solution is to determine the specific gravity of the liquid with an hydrometer and, by reference to Table 1, add the necessary quantity of alcohol to obtain the desired specific gravity. Care should be taken to have the solution thoroughly mixed and, as the specific gravities given in the table are obtained at 60 deg. fahr., the specific gravity should be measured when the temperature of the solution is between 55 and 65 deg. fahr. The solution can then be kept at the proper strength from day to day by adding alcohol until the hydrometer reads the same as when first noted.

To illustrate how a non-freezing solution is prepared by using Table 1, assume that the lowest temperature anticipated is 19 deg. above zero fahr. and that denatured alcohol is to be used. By reference to Table 1, in the line marked Denatured Alcohol, plus 19 deg. fahr. is found in the 20 per cent column and the specific gravity of that solution is 0.978. If the radiator holds 3.5 gal., 20 per cent of this must be alcohol and the remaining 80 per cent water. Twenty per cent of 3.5 gal is 0.7 gal. or a little more than 5.5 pints which is the quantity required. This should be added to enough water to make 3.5 gal.; that is, the water used will be 3.5 gal. less 0.7 gal. or 2.8 gal., a little more than 11 quarts. If the temperature of this solution is brought to 60 deg. fahr. and an accurate hydrometer is floated in it, the hydrometer should read 0.978. If the reading is higher than 0.978 more alcohol should be added with constant stirring until the 0.978 mark is reached. An accurate hydrometer should read 1.000 when placed in water at 60 deg. fahr. and 0.834 in 180-deg.-proof alcohol at the same temperature. The denatured alcohol usually sold by dealers is 180-deg. proof, which is the minimum allowed

TABLE 1—FREEZING-POINTS AND SPECIFIC GRAVITIES OF THE BUREAU OF STANDARDS ALCOHOL AND GLYCERINE ANTI-FREEZING SOLUTIONS

	Denatured Alcohol	Wood Alcohol	Glycerine	Denatured Alcohol and Glycerine[2]	Wood Alcohol and Glycerine[2]
10-Per Cent Solution[3]					
Freezing-Point, deg. cent.	−3	−5	−2	−4	−4
deg. fahr.	+27	+23	+29	+25	+25
Specific Gravity at 60 deg. fahr.	0.9880	0.9870	1.2537	———	———
20-Per Cent Solution					
Freezing-Point, deg. cent.	−7	−12	−6	−8	−9
deg. fahr.	+19	+10	+21	+18	+16
Specific Gravity at 60 deg. fahr.	0.9780	0.9750	1.2537	———	———
30-Per Cent Solution					
Freezing-Point, deg. cent.	−12	−19	−11	−13	−15
deg. fahr.	+10	−2	+12	+9	+5
Specific Gravity at 60 deg. fahr.	0.9680	0.9630	1.2537	———	———
40-Per Cent Solution					
Freezing-Point, deg. cent.	−19	−29	−18	−22	−24
deg. fahr.	−2	−20	0	−8	−11
Specific Gravity at 60 deg. fahr.	0.9570	0.9520	1.2537	———	———
50-Per Cent Solution					
Freezing-Point, deg. cent.	−28	−40	−26	−32	−35
deg. fahr.	−18	−40	−15	−26	−31
Specific Gravity at 60 deg. fahr.	0.9430	0.9370	1.2537	———	———

[2] Glycerine and alcohol are mixed in equal proportions; a 10-per cent solution of glycerine and alcohol, for instance, means that 5 parts of glycerine and 5 parts of alcohol should be added to 90 parts of water.

[3] Percentage, by volume, in water.

by law. A solution so prepared will not begin to freeze until its temperature is approximately plus 19 deg. fahr.

A careful consideration of the question of anti-freezing solutions for radiators leads to the conclusions that

(1) Calcium-chloride compounds should be used with caution, if at all, on account of their corrosive action
(2) Kerosene or similar oils should not be used on account of their inflammability, high boiling-point and effect on rubber
(3) Mixtures of glycerine and alcohol can be used, but the price of glycerine may preclude its use
(4) Solutions made from either wood or denatured alcohol seem at present to be the most desirable anti-freezing solutions to use. If the wood alcohol is free from acid there is little choice between the two. Wood alcohol costs more and is more volatile, but its lower freezing-point allows a less amount to be used, which may counteract the above disadvantage

Numerous tables have been published giving the freezing-points of certain water solutions containing alcohol, glycerine or a mixture of the two, but there is much disagreement in the figures. Table 1 gives freezing-points obtained from actual measurements made at the Bureau of Standards on solutions of commercial materials; it can be considered sufficiently accurate for practical purposes, since the freezing-points agree fairly well with the most reliable scientific data.

The freezing-point is taken to be that temperature in the cooling process at which crystals begin to form. The temperature at which the entire mass becomes solid may be several degrees lower than the freezing-point for dilute solutions, and 10 to 15 deg. lower for the more concentrated solutions. As an example, a 30-per cent solution of denatured alcohol begins to freeze at 7 deg. fahr., that is, small crystals of ice form, but the solution does not freeze solid until a temperature of 5 deg. below zero, or lower, is reached. Hence, a temperature considerably lower than that given in Table 1 for any given percentage of alcohol would not injure the engine or radiator. However, it seems desirable to keep the solution at such a concentration that ice crystals will not form at the lowest temperature to be encountered, since they may interfere with the circulation.

Method of Reading Hydrometer

The solution is placed in a clear glass jar or cylinder and the hydrometer carefully immersed in it to a point slightly below that to which it naturally sinks; it is then allowed to float freely. In taking the reading the eye should be placed slightly below the plane of the surface of the liquid and then raised slowly until this surface, seen as an ellipse, becomes a straight line. The point at which this line cuts the hydrometer scale should be taken as the reading of the instrument.

THE DISCUSSION

J. A. Secor:—I fully agree with all the conclusions Mr. Zimmerman reported except those relating to alcohol, regarding which I have no personal knowledge. I will present the following notes on oil-cooling.

Oil-Cooling

Oil-cooling of tractor engines has the advantage of adaptability to all climatic conditions and all atmospheric temperatures. In the past 11 years approximately 30,000 Oil-Pull tractors have been equipped with oil-cooling systems. There have been no complaints from the field relating to oil-cooling. Not more than two or three cases have been reported where water was used by the tractor owner in preference to oil, and these few exceptions were in tropical countries. The oil-cooling system is simple, requires little attention in the field and is almost foolproof. No time is lost in refilling the radiator in summer, or in draining and refilling in freezing weather, or in replacing broken belts. Power is not used for operating the fan. In place of the fan, the air for cooling the radiator is drawn through it by the inductive effect of the exhaust discharged from nozzles located in a hood placed over the radiator. The circulation of cooling oil from radiator to cylinder and return is made positive by a centrifugal pump of ample capacity driven by spur gears from the camshaft of the engine.

The tractor tests made in 1920 at Lincoln, Neb., by the State University, demonstrate that even in summer oil-cooling has incidental advantages. Sixty-five tractors were tested between April and October inclusive. In many respects these reports are conceded to "represent the greatest fund of tractor information available. The results may be taken as representative of average performance." The test reports show that on 23 occasions repairs were made to the fans or belts of 17 different tractors. Delays and expense from this source are eliminated throughout the entire life of an Oil-Pull tractor.

In the oil-cooling system there are no parts requiring readjustment or repair with the exception of an occasional replacement of the packing in the pump-gland; usually, about once in each season. The oil for cooling should be non-freezing, free from moisture, and have an initial boiling temperature above 500 deg. fahr. Zero Black, Winter Black, Gargoyle Arctic Oil C and Gargoyle Teleo Oil are trade names for such oils. Ordinary commercial Winter Black is commonly used. Owing to the differences between oil and water in respect to viscosity and heat conductivity, radiators designed for water-cooling are not usually suitable for oil-cooling. The Oil-Pull tractor has about 8 sq. ft. of cooling surface per rated brake-horsepower of the tractor, and ½-gal. volumetric capacity per brake-horsepower for filling jackets, connecting pipes and radiator.

There are numerous instances of motor vehicles in which kerosene has been successfully substituted for water for winter use, but the data as yet are insufficient to warrant any general conclusions regarding the feasibility of oil-cooling for automobiles. Kerosene has an average initial boiling-point of approximately 300 deg. fahr., whereas the initial boiling-point of the Winter Black oil used in tractors is from 550 to 575 deg. fahr. The general characteristics of Winter Black Oil are given in Table 2.

TABLE 2—CHARACTERISTICS OF WINTER BLACK OIL

Pour-Test, deg. fahr.	20
Viscosity at 104 Deg. Fahr., sec.	181
Viscosity at 210 Deg. Fahr., sec.	46½
Flash Test., deg. fahr.	345
Fire Test, deg. fahr.	385
Initial Boiling-Point, deg. fahr.	550
End-Point, deg. fahr.	750

The viscosity diminishes very rapidly as the temperature of Winter Black oil increases. Due to its relative viscosity at freezing temperatures, it is customary to add kerosene to Winter Black, thereby reducing its viscosity so that it can be pumped freely. As the weather becomes warmer, the kerosene appears to evaporate gradually and can be replaced with undiluted oil. Gargoyle Teleo Oil, however, has the advantage of the extremely low pour-test of 20 deg. fahr. The average temperatures of cool-

ing oil when discharged from the cylinder jackets lie between 150 and 225 deg. fahr., according to the model, load and speed of the engine. Its maximum operating temperature is always more than 100 deg. lower than its flash-point. Winter Black does not crack or deposit tarry material at its working temperatures. In fact, after 11 years of use in our early tractors, no cases have been reported where the interiors of the radiator or the jackets have been clogged by scale or deposits of any kind. However, only a suitable oil of known characteristics should be used for cooling.

A MEMBER:—There is no danger to the solder of the radiators at 225 deg. fahr. I think that ordinary radiators could be used for oil-cooling, except that the water passages would have to be made larger.

MR. SECOR:—The water passages are too small for oil, and the radiator capacity would have to be greater. Tubular radiators of sufficient capacity can be used for oil-cooling.

D. R. HARPER:—The foregoing remarks have suggested to me that there are two possible lines of improvement. One is to ascertain whether an anti-freeze solution can be found for use in the radiators already developed; and the other is to consider just what changes might be required in the radiator to make it better adapted to the most convenient fluid, whether that be water or another fluid that might give a wider range of use with equal convenience. I think there is no doubt in the minds of most of us that the latter is the course that will be followed. If there are liquids other than water that will be serviceable, every effort will be made to have the radiators designed so as to use them equally as well as water is used now. I suppose it was with that thought in mind that your Committee suggested that a member of the staff of the Bureau of Standards present a brief review of the factors that enter the radiator problem.

RADIATOR PROBLEM FACTOR

Our work at Washington has been primarily with respect to an application of these factors to aircraft, but the principles are the same as in the tractor problem, of course. There is a widely different application, but the fundamentals are the same. The methods that we followed in studying the factors for aircraft may be more or less similar to the methods that the tractor engineers will find worthwhile to use in attacking their problem. First, we had to consider from the purely engineering point of view, rather than from that of the details of a scientific study, what properties of a radiator have a bearing upon the problem. In my own analysis, I sketched six different considerations that should come in for the aircraft problem: (*a*) cooling capacity, (*b*) head-resistance, (*c*) weight, (*d*) appearance, (*e*) sturdiness of construction and ease of repair and, finally, (*f*) the cost. There we have six different problems interlocked. From the standpoint of aircraft radiators certain of these factors were of importance and others were not. For example, with the aircraft we could forget all about cost; we were working then primarily on the military machines and even if the radiator did cost 5 to 10 times more, it might soon save that cost in operating because of the greater reliability of the airplane. From every military consideration, cost was a very unimportant thing. In the commercial applications, where large quantities of passenger automobiles or tractors are produced, cost becomes one of the factors of great importance. The appearance of aircraft was something that we could neglect. Head-resistance was a matter of prime importance, and so was weight. Our problem, therefore, involved head-resistance, cooling capacity and weight.

Let us turn to the automobile industry, which preceded that of aircraft. Head-resistance is of small importance in the automobile, but the question of appearance is of very great moment, as the sales department of any automobile company will testify. It is something the engineer must take into consideration. Sturdiness and ease of repair never required undue attention on our part, not because the factor is unimportant, but because inventive ingenuity seems to have mastered that factor in almost any type of radiator core one can picture. In aircraft work it requires perhaps somewhat less than in the other cases because the air machines usually receive rather expert attention, but for the automobile or tractor I think sturdiness and ease of repair would be given a very prominent place. We can eliminate head-resistance from the scientific questions and, for the tractor, we can give comparatively little emphasis to weight; so that cooling capacity, it seems to me, is the only one that remains. That is, we want to consider cost as opposed to getting the radiator properly sturdy, properly accessible for repair and proper as regards cooling capacity. There are those four factors.

The scientific work that has been done in various laboratories of the industry, in the United States and in Europe, has given us comparatively little data on the radiator. We know in very general terms the conditions under which the radiator is working, but we have very few data as to just what specifications describe those conditions for the passenger automobile or for the tractor. So, our work at the Bureau of Standards, which was primarily with respect to aircraft, included a very careful study of the conditions under which the aircraft radiator would work; that is, primarily, how much air would go through the radiator. I think all the data regarding cooling that we have will be found directly applicable to the passenger automobile or tractor, just as soon as we have solved the other half of the problem, namely, what the conditions of airflow are in such types of radiator. While some of the industrial laboratories have done considerable work on that, it is my understanding that the reason the Tractor Division of the Society's Standards Committee is not getting very far in adopting any standards and definite specifications in the radiator problem is that there is a very small amount of correlated data as to the conditions of airflow in the different types of radiator as mounted in the various makes of car. The amount of heat that a radiator will dissipate depends primarily on the weight of air that is going through it. It is not directly proportional to airflow but, over moderate ranges of variation in flow, it is not very far from that.

Our work on the aircraft radiators in which air was forced through them at wind speeds of from 20 to 120 m.p.h. showed that for almost every type of core we tried, including some 70 or 80 types, a numerical equation would express the heat-transfer in which the term of which we are now speaking, the airflow per unit area, entered in a relation where it was raised to a constant power, generally about the eight-tenths power. That is, the total heat dissipated by the core, with all things constant except airflow, varied as the eight-tenths power of the airflow through the radiator. If a radiator is mounted on the front of an automobile and pushed through the air at a given driving speed without having the fan going, it does not mean that, of necessity, the air goes through the radiator at anything like the driving

speed. It will generally be less than the speed of the radiator relative to the air. One factor to bear in mind is that one cannot always deduce simply what conditions are being obtained for airflow through a radiator core from what is known of wind speed in front or behind that core. What we want to measure is the actual airflow through the core, not the airflow somewhere in front of the radiator, or at some certain distance behind it. Since the one definite factor to which we can tie in such work is the rate of airflow, we must always be able to specify the airflow through the core to apply any data that have been obtained, as, for example, our data on the aircraft-radiator work. Whenever, then, for the automobile or the tractor radiator, we have any data giving the airflow, this quantity raised to about the eight-tenths power is the factor to which the heat transfer is proportional. So, if we operate a fan so as to draw four times as much air per minute through it at one time as at another, we get about three times the heat transfer. While you thus see that the relation is not proportional, it is not far from it and we can have in mind that it is more or less approximately so and that if we double the airflow through the core we will nearly double the heat that will be taken away from the water for a certain surface and a given temperature-difference of the water and the air. The factor that seems to have received too little attention in the engineering consideration of this problem is the influence of the air-flow through the core. For example, very little attention has been paid to what becomes of the air after the fan has sucked it through the core; yet if the efflux openings are blocked up too much, we will have a back-pressure that makes the actual air that comes through the core very much less than the same fan at the same speed would pull through it in the open. For such reasons a wind-tunnel experiment under conditions that were erroneously supposed to be approximately similar to practical working conditions, is sometimes misinterpreted. So, as you go through these newer problems, the applications to the tractor-radiator design, do not forget the importance of the airflow through the core. The frontal area that is required will depend absolutely on what airflow is obtained through it. If we are to get twice as much air, we can cut down the frontal area by half. Head-resistance makes no difference in tractor work. There can be a large frontal area and a small depth, or a small frontal area and a large depth. It is a matter of convenience whether the radiator will be accessible; the one factor that is vital is that we get the airflow that will correspond to the frontal area and depth.

The question of waterflow or, more generally, if anti-freeze mixtures be used, the rate of fluid flow requires comparatively little attention, I think. We found in our work with the aircraft radiators that if the waterflow exceeded about 15 gal. per min. for 1 ft. width of core, where the core was about 4 or 5 in. deep, any waterflow in excess of that amount did not bring heat to the metal any faster than the air could take it away, for the ordinary core of any type considered. The usual pump system is delivering water at fully that speed, and the question of waterflow is principally that of having the passages wide enough that they will not clog. The whole problem of radiator action comes in getting the heat in the metal out to the air, and not in getting it from the water to the metal. The specific heat has importance in its bearing on the actual quantity of fluid that must be circulated, but the thermal conductivity can be minimized to a considerable degree. As I said, the fluid tends to get the heat into the metal so much faster than the air will take it away, that even with the great variation of conditions we encounter there is almost never a really significant difference in the temperatures of the metal and the water. Therefore, if we used a liquid of very much poorer thermal transmission properties, there would still be comparatively little temperature-drop between the metal and the liquid. The viscosity of any fluid other than water might have a considerable bearing on the rate of circulation, and upon the way the pump would work, and thus be very important in secondary ways, but it would hardly be a prominent factor in the heat-transmission considerations.

PROF. C. A. NORMAN:—I understand that the engineers of the London General Omnibus Co. have found that alcohol corrodes metal very badly. What observations have been made as to the possible corrosive action of these anti-freezing mixtures on the metal used in the radiators?

MR. HARPER:—With regard to corrosion, the chief difficulties have been stated to the Bureau of Standards to lie in the serious effects on copper and brass, rather than with the iron in the cooling circuit. I do not know how serious the trouble has been with radiators themselves, having had no occasion to take radiators apart that have had alcohol in them. I know something of corrosion from using alcohol in systems comprising copper and brass, and I feel it proper to express an opinion that it is necessary to consider corrosion more carefully as we come to more extended uses of alcohol. However, regarding the use of alcohol in radiators, I imagine that the degree of dilution decreases the corrosion factor very considerably, although I cannot be taken as an authority on this subject of corrosion.

CASEIN GLUES

CASEIN glues are as a class more water-resistant than animal and vegetable glues, but they are not, strictly speaking, waterproof. There is no glue that is unaffected by water, after a long immersion. Nevertheless, there are casein glues that are so water-resistant that plywood glued with them will withstand soaking for many weeks in water or exposure for many months to a warm, damp atmosphere. Under similar conditions animal and vegetable glues would lose their strength in a comparatively short time.

When casein-glue joints are kept fairly dry, they can be expected to retain their strength and remain unchanged for an indefinite period, as is the case with animal and vegetable glues. Water-resistant casein glue in a joint, kept constantly wet, will after a long time weaken, but it will ordinarily regain a considerable proportion of its strength if the joint is dried. In a study aimed to discover the reason casein glues ultimately decompose when kept moist, the Forest Products Laboratory, Madison, Wis., found that under certain condition the decomposition seemed to be due to a hydrolysis of the casein, undoubtedly brought about by the sodium hydroxide that is always present in casein glues. This should not be taken to mean that casein glues are unreliable and not durable enough for use in manufacturing plywood and other glued products. On the contrary casein glues are considered by the Laboratory as enduring as any under dry conditions, and the water-resistant casein glues are more enduring than animal or vegetable glues under wet or damp conditions.

Condensation Temperatures of Gasoline and Kerosene-Air Mixtures[1]

By Robert E. Wilson[2] and Daniel P. Barnard, 4th[3] *Illustrated with* Drawing and Charts

After pointing out that a very important factor in connection with carbureter and intake-manifold design and the automotive fuel problem in general is a knowledge of the temperatures at which air-fuel mixtures either begin to condense or are completely vaporized, a new, simple and reliable method for determining the temperatures of the initial condensation of fuels from air-fuel mixtures is described, together with an approximate method of determining the temperatures of partial condensation in such mixtures. Vapor-pressure data on three typical automotive fuels are presented, supplemented by a series of charts showing the condensation temperatures of kerosene, gasoline and an artificially prepared high end-point gasoline under different conditions. It is pointed out in connection with the charts that inefficient methods of securing vaporization are responsible to a greater extent for the failure to obtain complete vaporization of present-day gasoline than any inherent limitation of the fuel itself.

A suggested method for approximating roughly the initial-condensation temperatures of paraffin hydrocarbon fuels from their distillation curves is outlined. A table giving the more important characteristic properties of the fuels investigated is included.

Acknowledge of the temperature at which various mixtures of internal-combustion engine fuels and air are completely vaporized, or just begin to condense, is of great importance in connection with the design of carbureters and intake manifolds and the automotive fuel problem in general. To secure satisfactory distribution between the different cylinders a fuel must be completely vaporized. This can be accomplished by heating the fuel, the air or the resulting mixture. If, however, the amount of heating is more than that required to vaporize the fuel, serious losses are encountered from the decreased capacity of the engine for the hot mixture, and the increased tendency toward knocking. From this standpoint it is important to know what minimum temperature must be reached to make complete vaporization possible, and then improve the efficiency of the mechanical devices for the vaporization of the fuel until substantially complete vaporization is obtained without appreciably exceeding this theoretically minimum temperature.

The suitability of kerosene and other fractions as fuels for internal-combustion engines, the proper end-point for gasoline and other important fuel problems depend to a considerable extent upon the dew-point of the fuel-air mixtures, that is, the temperature at which vaporization is complete or at which condensation begins on cooling.

In spite of the obvious importance of this information the authors have been unable to find any published information as to the dew-point of mixtures of the commoner fuels with air in the customary proportions. In fact, practically the only discussion of the problem is a very interesting paper[4] by Frank A. Howard entitled the Volatility of Internal-Combustion Engine Gasoline. This paper points out the importance of the problem and describes some experiments on gasoline which lead to certain practical conclusions. Although these conclusions are sound, the experimental results do not give any definite information as to the condensation point of gasoline under service conditions. There appear to be no data whatever on kerosene-air mixtures.

Methods of Determining the Condensation Points of Fuel-Air Mixtures

The most direct method of determining the dew-point of mixtures of air and gasoline would be to introduce a small, accurately weighed amount of gasoline into a flask containing a known volume of air, close all outlets, raise the temperature of the mixture until the gasoline was completely vaporized, and then cool very slowly until a mist of gasoline began to deposit on the walls of the flask; or better, on an internally cooled mirror, such as that used by McBain[5] in his work on soap solutions. By recording the pressure and temperature at which condensation began it should be possible to obtain a fairly accurate value for the dew-point of a particular mixture at a given pressure. The most serious objection to this method lies in the fact that a new sample must be weighed out accurately for each separate determination and that a large number of determinations must be made to determine the properties of a given fuel over the ordinary range of mixture ratios and pressures which are of interest. The Bureau of Standards has made some determinations by this method, but reports that the results thus far obtained are not considered satisfactory.

It might be suggested that the desired information could be obtained more simply by making vapor-pressure measurements, as in the case of pure compounds. The difficulty involved in this suggestion is the fact that gasoline is a mixture of compounds that differ widely in volatility and the vapor pressure of the original gasoline bears no relation to the vapor pressure of the fraction that first condenses out on cooling a completely vaporized mixture. If, however, it were possible to secure any considerable quantity of this fraction that first condenses out from, and hence is in equilibrium with, the completely vaporized mixture, measurements of its vapor pressure would obviously give the data desired.

It might at first sight be assumed that the composition of the fraction that first condenses out would be the same as that which was last distilled off in an ordinary distillation; but this is far from being the case, as a little consideration will show. The material that last distills out of the flask is in equilibrium with the vapor that is leaving the flask at that moment, and not with the completely vaporized gasoline as a whole. For this reason

[1] From a paper presented at a meeting of the American Chemical Society.

[2] Director of research, Massachusetts Institute of Technology, Cambridge, Mass.

[3] Research associate, Massachusetss Institute of Technology, Cambridge, Mass.

[4] See The Journal, February, 1921, p. 145.

[5] See *Journal of American Chemical Society*, vol. 42, p. 426.

the data obtained by Howard on the vapor pressure of the least volatile portion of the gasoline, the last 10 per cent distilled off, do not in any sense determine the temperature at which the mixture as a whole would begin to condense.

If a large volume of completely vaporized gasoline were run through a condenser whose temperature was gradually lowered until condensation just began, it is conceivable that a small amount of condensate might be secured that would represent fairly well the composition of the equilibrium mixture whose vapor pressure is desired. Any such device would, however, be open to serious question because of the necessary existence of a temperature gradient from the center of the stream to the walls, and the probability is that most of the condensate would come from that part of the vapors nearest the walls, and would not be in true equilibrium with the mixture as a whole. On account of these difficulties, the

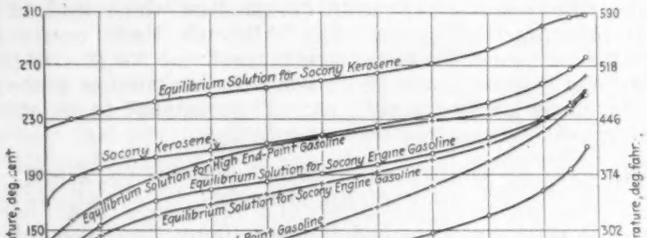

Equilibrium Solution for Socony Kerosene
Socony Kerosene
Equilibrium Solution for High End-Point Gasoline
Equilibrium Solution for Socony Engine Gasoline
Equilibrium Solution for Socony Engine Gasoline
High End-Point Gasoline
Socony Engine Gasoline
Temperature, deg. cent.
Temperature, deg. fahr.
Distilled, per cent

FIG. 1—DISTILLATION CURVES OF VARIOUS FUELS AND THEIR EQUILIBRIUM SOLUTIONS

Massachusetts Institute of Technology laboratory has developed a new method of obtaining a considerable amount of the desired equilibrium solution and by measuring its vapor pressure is able to calculate accurately the initial condensation temperature for any given mixture and the total pressure within the range of ordinary practice. By combining these data with data on the vapor pressure of the original gasoline it is also possible to determine approximately the percentage condensed under any given set of conditions.

It must be emphasized at the outset that results secured by such methods represent the conditions prevailing at equilibrium. It is possible to obtain "wet" mixtures at temperatures well above the dew-point, because the drops of the fuel that are sprayed into the airstream do not have sufficient time to absorb heat and vaporize before the mixture reaches the engine. The results simply indicate what is theoretically obtainable if the time, the degree of atomization, etc., are sufficient to permit equilibrium to be approached fairly closely.

Practical experience with present-day fuels indicates that on account of the limited time available it is necessary to separate out and apply heat to the unvaporized drops by direct contact with metal surfaces, as in various types of hot-spot manifolds, etc.

EXPERIMENTAL METHODS

In this work three different representative fuels were selected for investigation; their distillation curves are shown in Fig. 1. The gasoline had an initial boiling-point of 60 deg. cent. (140 deg. fahr.) and an end-point of 211 deg. cent. (411.8 deg. fahr.) and a specific gravity of 0.743. Its average boiling-point is fairly typical, but its boiling range is somewhat narrower than the average present-day product. The initial boiling-point of the kerosene was 168 deg. cent. (334.4 deg. fahr.), the end-point 282 deg. cent. (539.6 deg. fahr.), and the specific gravity 0.800. An artificially prepared high end-point gasoline consisting of a blend of 100 parts of engine gasoline and 25 parts of the lighter 50 per cent fraction obtained by distilling kerosene at atmospheric pressure was investigated. The initial boiling-point of this mixture was 62 deg. cent. (143.6 deg. fahr.), the end-point 252 deg. cent. (485.6 deg. fahr.), and the specific gravity 0.752.

To calculate the partial pressure of the fuel in a 15 to 1 mixture it is necessary to know the approximate average molecular weight of the fuel. The average molecular weights as used in this work were determined with sufficient accuracy by first obtaining their distillation curves and from these curves plotting the differential distillation curves shown in Fig. 2. This form of the distillation curve, obtained from the customary form by plotting the percentage coming over between each 10 deg. cent. or 20 deg. fahr. against the median boiling-point of the fraction, plotting the percentage over between 80 and 90 deg. cent. (176 and 194 deg. fahr.) against the temperature of 85 deg. cent. (185 deg. fahr.) is much more useful in comparing different fuels and detecting the presence of added constituents, such as benzene, that give a sharp peak in the curve near their boiling-points. Rigidly this method is undoubtedly inaccurate but, since an error of 10 per cent in the molecular weights would change the condensation temperatures by only 2 or 3 deg., it was not considered worthwhile to spend the amount of time involved in an accurate determination, especially in view of the great variations between different samples of commercial gasolines. The average boiling-point was taken as the point at which a perpendicular passed through the center of gravity of the area bounded by the curve and the X-axis cut this axis. The distillation tests were made in a standard Engler still, using 100-cc. (6.1-cu. in.) samples. The average boiling-points determined as stated above, and the molecular formulas and weights of saturated paraffin hydrocarbons most nearly, within 2 or 3 deg. cent. (3.6 or 5.4 deg. fahr.), corresponding to these weights, are given in Table 1.

TABLE 1—PROPERTIES OF FUELS TESTED

Fuel	Kerosene	Gasoline	High End-Point Gasoline
Average Boiling-Point, deg. cent.	220.0	128.0	147.0
Average Boiling-Point, deg. fahr.	428.0	262.4	296.6
Corresponding Formula	$C_{12}H_{26}$	C_9H_{18}	C_9H_{20}
Average Molecular Weight	170	114	128

The partial pressures of the fuels in the different mixtures were calculated after the following example for a 15 to 1 kerosene-air mixture in which the partial pressure of kerosene at a total pressure of 1 atmosphere is equal to

$$[(1/170) \div (1/170 + 15/29)] \times 760 = 8.55 \text{ mm.}$$

As has been pointed out, to determine the initial condensation point of a fuel-air mixture it is necessary to prepare a considerable amount of a so-called "equi-

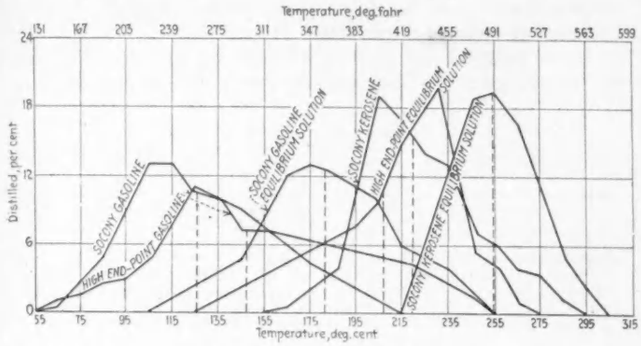


FIG. 2—DIFFERENTIAL DISTILLATION CURVES OF VARIOUS FUELS AND THEIR EQUILIBRIUM SOLUTIONS

librium solution" whose composition is in precise equilibrium with the uncondensed fuel at its dew-point. This solution was prepared in a glass still arranged for continuous operation as shown at the left of Fig. 3. The amount of liquid in the flask was kept constant at all times by carefully adjusting the rate of supply to that of condensate discharge, the level being measured by a small glass hook gage. The temperature of the oil-bath was also kept fairly uniform.

At first the composition of the fuel in the flask, as well as consequently its boiling-point, was identical with that of the original fuel; the vapor that passed off was, however, richer in the more volatile constituents, and hence as the distillation proceeded the solution contained more and more of the less volatile materials and its boiling-point rose. After four or five times as much liquid had passed through the flask as was held there, the temperature of the boiling liquid soon reached a constant maximum-point, after which the distillation was continued, keeping all conditions constant, until two or three more times the volume of the liquid in the flask had been distilled over.

By this time a dynamic equilibrium had certainly been definitely established, and since input must equal output, the composition of the vapor leaving the flask must then have been exactly equal to that of the original liquid entering. But the liquid in the flask was in equilibrium with this outgoing vapor, and it therefore had the same composition as that of the liquid that would first condense out from the vapor at its dew-point. Furthermore, enough of the liquid was then secured not only to measure its vapor pressure, but also to determine its distillation range compared with that of the original fuel.

The only remaining uncertainty involved is whether the composition of this equilibrium mixture is substantially the same at different temperatures. To settle this point two equilibrium solutions were prepared from the same gasoline, one with the flask at atmospheric pressure, and one at about 13-cm. (5.1181-in.) absolute pressure, this changing the boiling-points by about 60 deg. cent. (140 deg. fahr.). The distillation curves for these two solutions are given in Fig. 1. Careful measurement of the vapor pressures showed that the variations between the dew-points as determined from the two solutions in no case exceeded 3 deg. cent. (5.4 deg. fahr.). All other equilibrium solutions were prepared at about 13-cm. (5.1181-in.) pressure, so as to approach reasonably closely to the comparatively low temperatures at which condensation takes place from air-fuel mixtures.

It will be noted from the differentiated form of the distillation curves shown in Fig. 2 that the average boiling point of the equilibrium solution falls approximately at the 85-per cent point of the original fuel, and contains a considerable amount of material boiling as low as the 50-per cent point. This would be expected, since the first per cent or two distilling off of the equilibrium solution should have the same composition and average boiling-point as that of the original solution. The presence of some of the more volatile constituents is, of course, due to the fact that they dissolve in, and have their vapor pressure lowered by, the less volatile constituents. The foregoing illustrates the fallacy of assuming that the extreme high end of the distillation curve determines the initial condensation temperature of the fuel, or that any arbitrary selection of a high fraction of fuel can properly represent the composition of the equilibrium solution.

Two vapor-pressure curves for each fuel were experimentally determined; the vapor-pressure curve of the original fuel, which corresponds to the vapor pressure exerted by the completely condensed fuel; and the vapor-pressure curve for the equilibrium solution which represents the first drop that condenses out of a completely vaporized mixture.

The vapor pressures were measured at different temperatures in the apparatus sketched at the right of Fig. 3. The bulb was about 80 per cent filled with the liquid to be measured, and the U-tube was half-filled with mercury. This U-tube, being immersed in the constant-temperature bath, served to prevent the vapor from condensing in the manometer, as it would otherwise do. The pressure in the space between the U-tube and the manometer was adjusted by the stopcocks, so as to keep the liquid in the U-tube exactly level whenever readings were taken. The pressure exerted by the liquid was then equal to the barometer reading minus the difference between the height of the two manometer columns. Care was taken, when starting a series of observations, to boil off under a high vacuum a very small part of the liquid, to free the apparatus of all traces of air. As the bulb held about 40 cc. (2.441 cu. in.) and the amount lost in this manner was never over 0.2 cc. (0.0122 cu. in.), the error involved was so small as to be entirely negligible.

Most of the measurements were made by increasing the temperature in a stepwise fashion, only a few minutes being required to reach equilibrium at a given temperature. All results were checked by repeating the experiments on separate samples. It was found impracticable to check all points by lowering the temperature in a stepwise fashion, as temporary condensation of the vapor in the glass walls of the vessel and in the manometer arm, instead of in the liquid of the flask, made

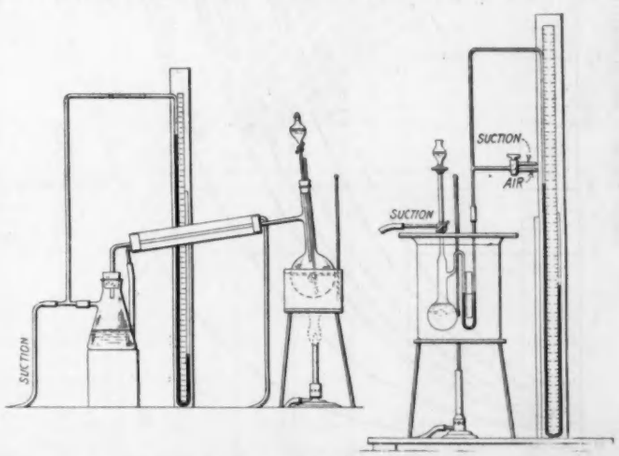


FIG. 3—APPARATUS AT THE LEFT FOR THE PREPARATION OF THE EQUILIBRIUM SOLUTIONS AND AT THE RIGHT THAT EMPLOYED FOR DETERMINING THE VAPOR PRESSURE

necessary a long wait before equilibrium was obtainable. In two attempts that were made to check by this means the pressure reading kept dropping very slowly for over 1 hr., but finally reached an equilibrium value which approximated very closely the value obtained in a much shorter time by raising the temperature.

To make possible a critical study of the vapor-pressure observations and also extrapolations of them with much greater accuracy than is obtainable on an ordinary vapor-pressure plot where the curvature is high, the results of observations were plotted on semi-logarithmic paper, the vapor pressures being plotted along the log scale, against the reciprocals of the absolute temperatures in degrees Kelvin along the arithmetic scale. Then if the modified form of the Clapeyron equation, which assumes the validity of the perfect gas law, holds for the mixture in question, the experimental points plotted as stated above should lie along a straight line if the heat of vaporization of the liquid is constant over the temperature range covered, or along a slightly curved line if the heat of vaporization varies with the temperature.

The fact that these log plots are straight lines, which is probably true only for fuels which consist essentially of similar hydrocarbons, and not for blends containing benzene, alcohol, etc., indicates that the heat of vaporization is actually substantially constant over the temperature range covered, and this in turn means that the specific heats of the liquid and vapor at any given temperature are nearly equal. The fact that the points all lie on a straight line makes possible the accurate extrapolation of the vapor-pressure curve into the low-pressure range, where, because of their small magnitude, the pressures are relatively difficult to measure with precision. As the gas laws hold more and more rigidly the lower the pressures, these extrapolated curves are much more accurate than could be determined experimentally without the use of special apparatus.

As is pointed out in the succeeding article, the heats of vaporization as determined from the slopes of these curves agree very closely with those determined by calorimetric methods by different investigators.

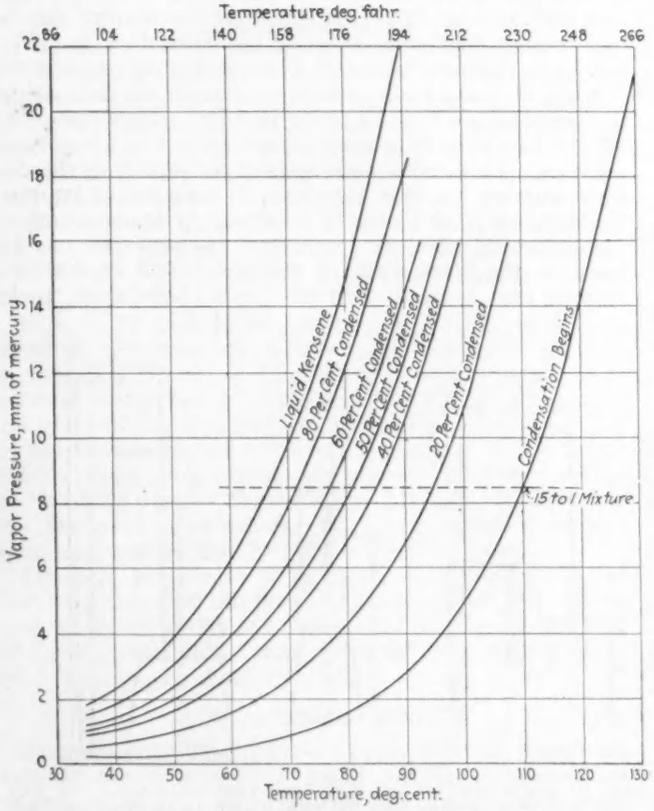

Temperature, deg. fahr.
86 104 122 140 158 176 194 212 230 248 266
Vapor Pressure, mm. of mercury
Liquid Kerosene
80 Per Cent Condensed
60 Per Cent Condensed
50 Per Cent Condensed
40 Per Cent Condensed
20 Per Cent Condensed
Condensation Begins
15 to 1 Mixture
30 40 50 60 70 80 90 100 110 120 130
Temperature, deg. cent.

FIG. 4—VAPOR-PRESSURE CURVES FOR KEROSENE

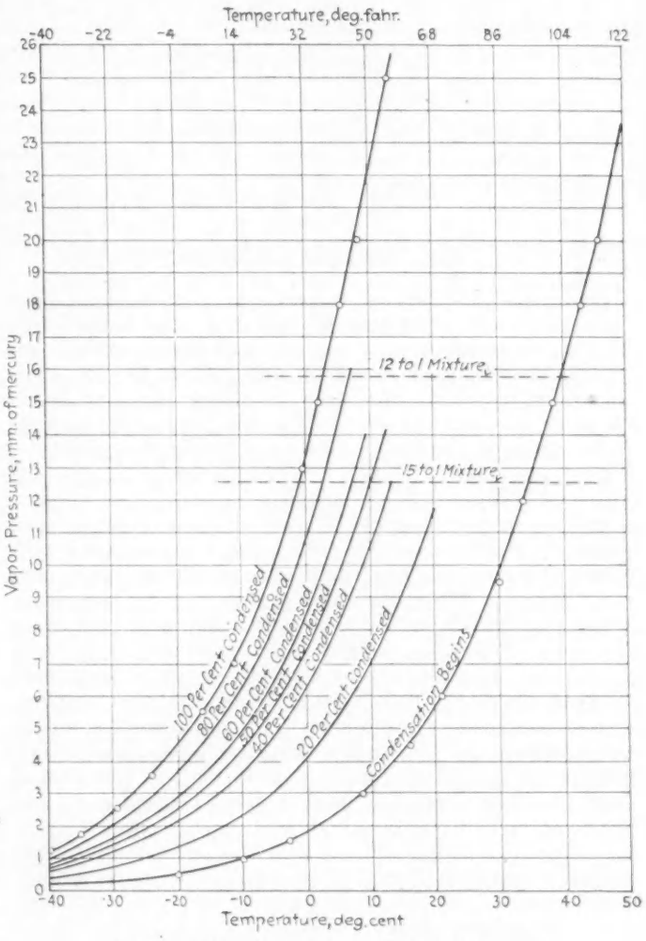

Temperature, deg. fahr.
-40 -22 -4 14 32 50 68 86 104 122
Vapor Pressure, mm. of mercury
12 to 1 Mixture
15 to 1 Mixture
100 Per Cent condensed
80 Per Cent Condensed
60 Per Cent Condensed
50 Per Cent Condensed
40 Per Cent Condensed
20 Per Cent Condensed
Condensation Begins
-40 -30 -20 -10 0 10 20 30 40 50
Temperature, deg. cent

FIG. 5—VAPOR-PRESSURE CURVES FOR GASOLINE

The upper curves on the log plots, the vapor-pressure curve for the equilibrium solution, represent the vapor pressures of the first drop which condenses out of an air-fuel mixture. The lower curves for the original fuel represent the vapor pressures of the 100-per cent condensed liquids. Experimental determinations of the vapor pressures of partially condensed vapors would be extremely difficult. Approximate figures for the various partial-condensation temperatures were therefore determined by assuming that the liquid obtained by condensing 40 per cent of the vapor exerted a pressure corresponding to a value 40 per cent of the distance from the totally vaporized line to the completely condensed line. The various figures for "per cent condensed" used hereinafter refer to the percentage lowering of the partial pressure and hence of the number of molecules of the vapor in the air, rather than the percentage by weight of liquid recovered. Since the first part of condensate consists on the average of heavier molecules, 50 per cent condensed in the above described sense would correspond to possibly 55 per cent by weight condensed. A study of the accurate data available in the literature on the vapor pressure of mixtures of octane and decane showed that

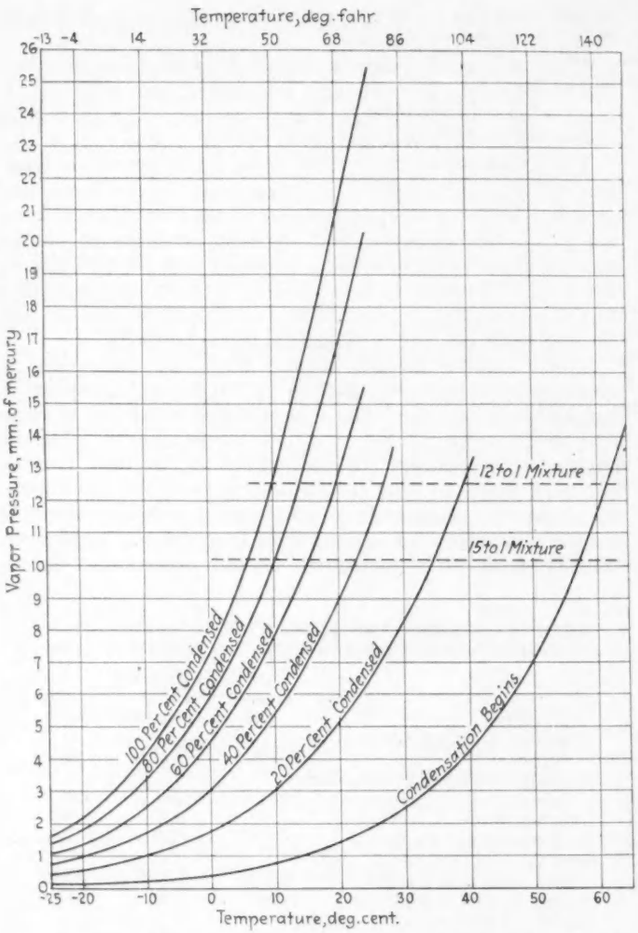

Temperature, deg. fahr
-13 -4 14 32 50 68 86 104 122 140
Vapor Pressure, mm. of mercury
Temperature, deg. cent.
-25 -20 -10 0 10 20 30 40 50 60
100 Per Cent Condensed
80 Per Cent Condensed
60 Per Cent Condensed
40 Per Cent Condensed
20 Per Cent Condensed
Condensation Begins
12 to 1 Mixture
15 to 1 Mixture

FIG. 6—VAPOR-PRESSURE CURVES FOR A MIXTURE COMPOSED OF 100 PARTS OF GASOLINE AND 25 PARTS OF KEROSENE

this held true to within 5 or 6 per cent. This is certainly near enough to the truth for the purpose at hand, as far as paraffin hydrocarbons are concerned. Figs. 4, 5 and 6

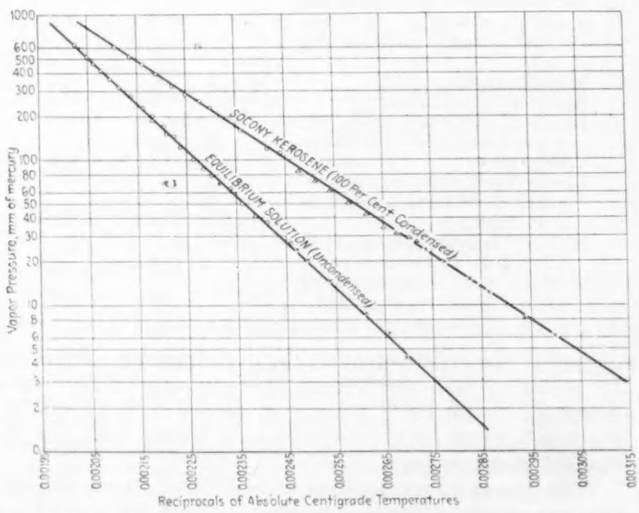

Vapor Pressure, mm. of mercury
SOCONY KEROSENE (100 Per Cent Condensed)
EQUILIBRIUM SOLUTION (Uncondensed)
Reciprocals of Absolute Centigrade Temperatures

FIG. 7—LOGARITHMIC CURVES OF VAPOR PRESSURE OF KEROSENE AND ITS UNCONDENSED EQUILIBRIUM SOLUTION

show the vapor pressures exerted by the various fuels, when condensed to different extents, over the range covered by the air-fuel mixtures used in internal-combustion engines, plotted directly against the temperatures in degrees centigrade. To determine, for example, the temperature at which kerosene is 40 per cent condensed from a 15 to 1 mixture at 1 atmosphere pressure, it is only

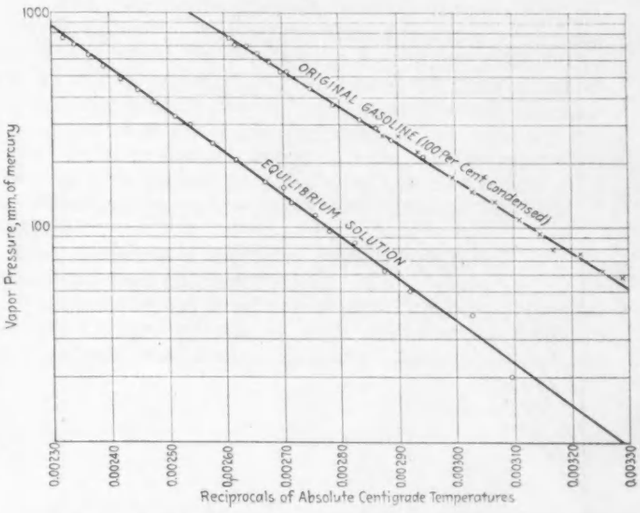

Vapor Pressure, mm. of mercury
ORIGINAL GASOLINE (100 Per Cent Condensed)
EQUILIBRIUM SOLUTION
Reciprocals of Absolute Centigrade Temperatures

FIG. 8—LOGARITHMIC CURVES OF THE VAPOR PRESSURE OF GASOLINE AND ITS EQUILIBRIUM SOLUTION

necessary to find the temperature corresponding to the point on the "40-per cent condensed" curve which indicates a vapor pressure equal to 60 per cent of the vapor pressure of the entirely vaporized fuel, in this case 8.55 mm.

$$0.60 \times 8.55 \text{ mm.} = 5.10 \text{ mm.}$$

5.10 of the "40-per cent" curve corresponds to a temperature of 73 deg. cent. (163.4 deg. fahr.). Kerosene is therefore approximately 40 per cent condensed from a

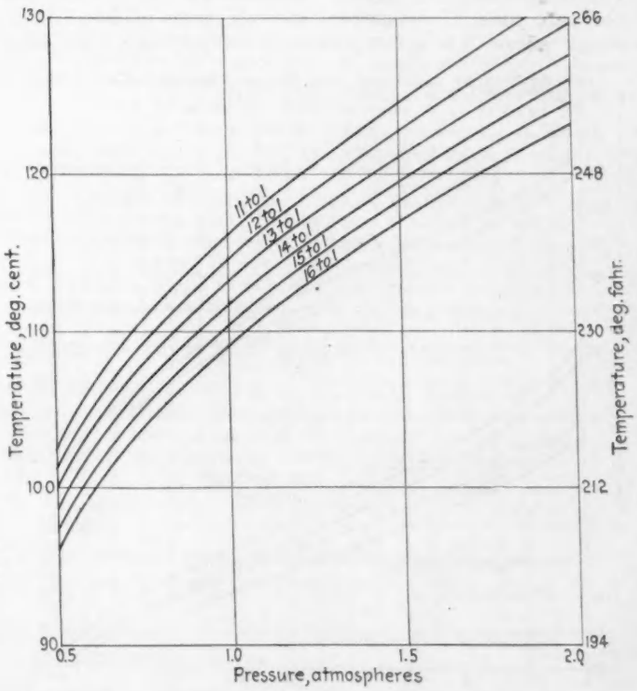


FIG. 9—CURVES OF INITIAL CONDENSATION TEMPERATURES FOR VARIOUS KEROSENE-AIR MIXTURES

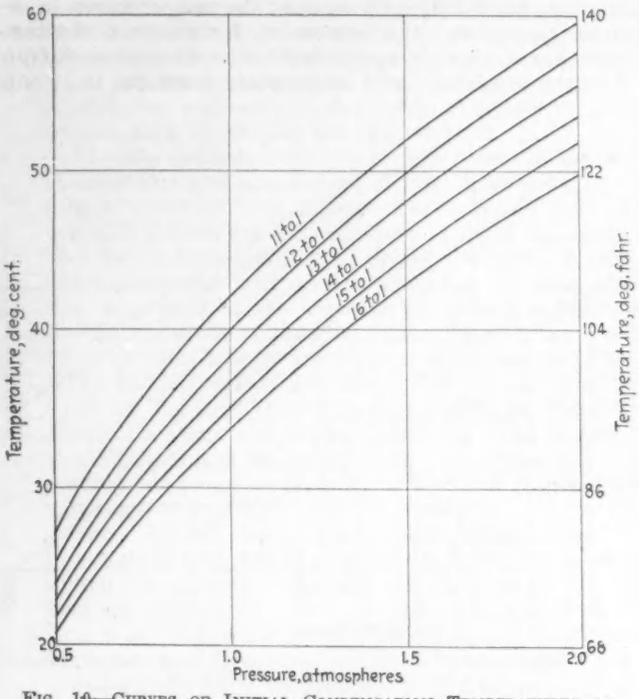


FIG. 10—CURVES OF INITIAL CONDENSATION TEMPERATURES OF VARIOUS GASOLINE-AIR MIXTURES

15 to 1 mixture under 1 atmospheric pressure at a temperature of 73 deg. cent. (163.4 deg. fahr.).

DISCUSSION OF RESULTS

The data are all presented in graphic rather than tabular form and are for the most part self-explanatory. The experimentally determined vapor-pressure values are indicated on the log plots, Figs. 7 and 8. It will be noticed that they fall very satisfactorily on straight lines. Although the lines appear to converge before reaching the zero axis, if measurements had been made at pressures above 1.5 atmospheres it is probable the lines would have begun to curve apart, due to large deviations from the perfect gas laws.

Figs. 4, 5 and 6 are replotted directly from the best representative lines on the log plots, and Figs. 9, 10 and 11 are plotted from values calculated as indicated above from the vapor-pressure curves.

These curves, as their titles indicate, show respectively the initial condensation temperatures for kerosene and gasoline under different pressures over the range from 0.5 to 2.0 atmospheres, and the temperatures of partial condensation at atmospheric pressure for all three fuels for a 12 to 1 and a 15 to 1 air-fuel mixture, representing fairly closely the composition for maximum power and theoretically perfect combustion respectively.[6]

These results indicate clearly that any difficulties in securing complete vaporization of the present commercial gasoline are not due to any inherent limitation in the gasoline itself, or to too low manifold-temperatures, once the engine is warmed up. Indeed, where any serious attempt has been made to heat the incoming gases or the intake-manifold, the temperature attained by the airstream is almost invariably far higher than theoretically necessary. Improvement in vaporization should apparently be secured by better atomization, longer times of contact or by throwing the unvaporized particles out of the insulating airstream on to a hot-spot, rather than by raising the temperature of the mixture as a whole, with the attendant disadvantages of this.

With the same precautions as suggested above, raising the temperature of the intake-manifold only slightly above present practice should make possible the utilization of fuels of considerably higher end-point, as far as completeness of vaporization and proper distribution are concerned.

It will be noted from the curve in Fig. 2 that the

[6] See *Journal of Industrial and Engineering Chemistry*, vol. 13, p. 51, and THE JOURNAL, June, 1921, p. 543.

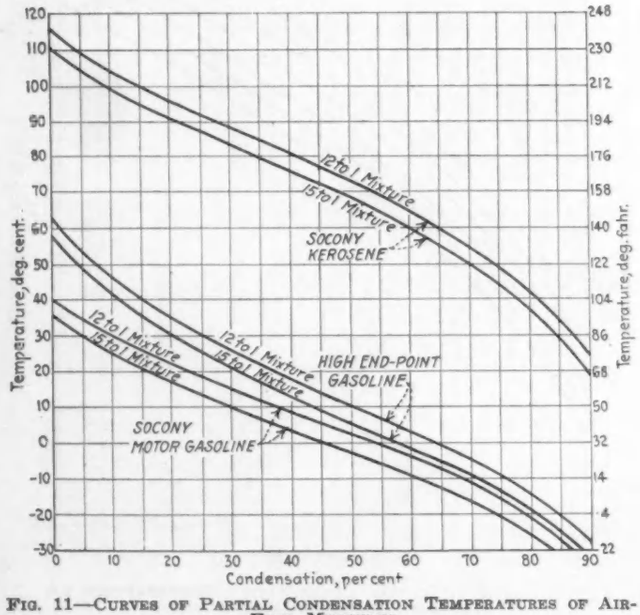


FIG. 11—CURVES OF PARTIAL CONDENSATION TEMPERATURES OF AIR-FUEL MIXTURES

TABLE 2—SUMMARY OF THE PHYSICAL CONSTANTS OF THREE TYPICAL FUELS AND THEIR MIXTURES WITH AIR

Fuel	Fuel Gasoline	High End-Point Gasoline	Kerosene
Average Boiling-Point, deg. cent.	128.0	147.0	220.0
Average Boiling-Point, deg. fahr.	262.4	296.6	428.0
Average Molecular Weight	114	128	170
Corresponding Formula	C_8H_{18}	C_9H_{20}	$C_{12}H_{26}$
Specific Gravity at 20 deg. cent. (68 deg. fahr.)	0.743	0.752	0.800
Baumé Gravity, deg.	60	57	45
Initial Boiling-Point, deg. cent.	60	62	168
Initial Boiling-Point, deg. fahr.	140	144	334
50 Per Cent Distilled, deg. cent.	128	154	219
50 Per Cent Distilled, deg. fahr.	262	309	426
85 Per Cent Distilled, deg. cent.	169	208	249
85 Per Cent Distilled, deg. fahr.	336	403	480
End-Point, deg. cent.	211	252	282
End-Point, deg. fahr.	412	485	539
Initial Condensation Temperature from 12 to 1 Mixture, deg. cent.	40	63	116
Initial Condensation Temperature from 12 to 1 Mixture, deg. fahr.	104	134	242
50 Per Cent Condensed from 12 to 1 Mixture, deg. cent.	2	9	73
50 Per Cent Condensed from 12 to 1 Mixture, deg. fahr.	36	48	163

average boiling-points of the equilibrium mixtures fall very close to the temperature at which 85 per cent of the original fuel has been boiled off, as indicated by the standard distillation curves. There is apparently some, though a not at all rigid, connection between these two points, for if, in each case, 135 deg. cent. (243 deg. fahr.) be subtracted from the "85-per cent off" temperature, the result is a rough approximation, within 5 or 10 deg. cent. (9 or 18 deg. fahr.) to the initial condensation temperature of a 12 to 1 mixture at 1 atmosphere. This fact may serve as a means of estimating roughly the initial condensation temperatures of paraffin hydrocarbon fuels from a mere inspection of their distillation curves. The reason for this rather surprising relationship probably lies in the approximate equality of the heats of vaporization, and hence of the rate of change of vapor pressure with temperature, of the paraffin hydrocarbons. It would certainly not apply to fuels containing alcohol, benzene, etc.

Attention should be called also to the fact that the temperature at which the various original fuels exert a given vapor pressure is a comparative measure of the ease of starting in cold weather, provided there is sufficient priming. The minimum possible starting-temperature is, however, probably 30 or 40 deg. below the minimum temperature at which the fuel exerts a pressure sufficient to give a combustible mixture, because of the heating effect of the compression stroke before the ignition of the mixture of fuel and air is accomplished.

The vapor-pressure curves for the partly condensed mixtures give an indication of what can be accomplished as to starting in cold weather with various amounts of choking.

Table 2 compares the three fuels investigated in their more important characteristics.

It is hoped to continue this work further by determining the foregoing type of data for various types of blended fuels, naphthene base fuels, etc.

STARTING ON ALCOHOL

AT first sight some of the statements made in this article, taken from *The Motor* (London), appear to contradict known facts regarding vaporization and ignition of alcohol. Adiabatic compression always increases the vaporization and lowers the ignition temperatures of this substance and seems to favor easy starting. On the other hand, isothermal compression or compression at a constant temperature, *decreases* vaporization very decidedly. Compression at the ordinary speed of cranking is certainly far from adiabatic and may very possibly tend to retard rather than to promote evaporation. In any case, a reduction of pressure in the intake-manifold promotes evaporation.

It is interesting to note that the method finally recommended for starting with alcohol does not differ at all from the practice that has been developed in the United States for starting on the grades of gasoline marketed here. Apparently the British engineers have not had so much experience with low-grade fuels.

THIS Australian Alcohol Fuel Committee, while admitting that big problems remain to be solved in respect of the production and denaturation of power alcohol, has taken a step in the right direction by successfully tackling the problem of starting, from the cold, engines of normal design using alcohol alone as a fuel. Hitherto the general impression has been that, when this fuel is used without the admixture of ether or some other volatile substance, the use of a preheating device or the starting and warming-up of the engine on some other fuel is necessary when starting from dead cold.

Low Compressions

It is, of course, known that the use of alcohol favors the use of very high compressions, as giving better efficiency. Experiments have therefore tended in the direction of increased compressions, but it was observed that, though engines using alcohol would not start from the cold, the unexploded charge issuing from the exhaust could be easily ignited. Consequently the effect of reducing instead of increasing the compression was tried in an engine with an adjustable connecting-rod. The experiments started with compression at 60 lb. per sq. in., in which circumstances the engine gave no sign of starting from the cold. The cylinder was primed with fuel and the compression gradually reduced, attempts to start up being made at each stage. The first signs of an explosion occurred at a compression of 43 lb. At 34 lb. the engine fired regularly, and the best results were obtained between 35- and 25-lb. compression.

Subsequently it was found that the best way of reducing the compression was by controlling the admission of air. A large number of experiments were made. In a typical instance the engine of a 25-hp. Vauxhall car was started by placing a leather disc over the air-intake on the White and Poppe carbureter, admitting a little methylated spirit through the priming-cocks, and then cranking.

An extreme case of a successful experiment was that of a single-cylinder engine that started from the cold on alcohol after being packed in ice. Another engine was started regularly from the cold on 70 consecutive mornings at the first attempt without a single failure, the atmospheric temperature being sometimes as low as 9 deg. cent. (48 deg. fahr.).

Requirements for Using Pure Alcohol

Similar successes have been achieved with various types of engine, air-cooled and water-cooled, four-cycle and two-cycle. The conclusions reached are that the greatest ease of starting from the cold is secured under the following conditions:

(1) The throttle must be a good fit, but not entirely airtight
(2) The extra-air supply must be completely shut off
(3) The engine should be primed with a little alcohol fuel
(4) The crankshaft should be turned slowly to distribute the priming charge

Subject to these preliminaries, it is found that, by rotating the starting-handle at a fair rate, the engine picks up with certainty on the third or fourth compression-stroke.

A Survey of Oxyacetylene Welding

By Lorn Campbell, Jr.[1]

Minneapolis Section Paper

THE author discusses oxyacetylene welding as a factor of efficiency in manufacturing and states three reasons why rivets are being replaced by welds. Recommended practice with special reference to welding mild steel with the oxyacetylene flame is outlined and commented upon, the importance of the human element as a factor in successful welding being emphasized, as well as the necessity of drawing a much finer line than that of the neutral flame, necessary in welding most metals, when welding steel.

Steel-welding apparatus is described and commented upon and the subject of filler-rods considered. In testing welds it is necessary to break the weld so that the interior can be inspected for penetration, adhesion and oxidation.

LEADING economists inform us that henceforth the most successful manufacturing enterprises will be the ones operating along the most efficient lines. The wide-awake engineer will give due consideration therefore to the process of welding. Manufacturers of steel products, such as the various types of barrels, tanks and pressure vessels, should pay particular attention to their design so as to turn out the strongest and most efficient product at a low cost.

Rivets are being replaced rapidly by the weld. The three reasons this should be done are that (*a*) by securing a permanent seam that will not leak a better product can be obtained that will withstand more abuse, (*b*) the cost is reduced greatly and (*c*) if necessary repairs can be made readily. If a seam along a line of rivets opens, it is very difficult to make repairs under ordinary conditions, but if a crack is found in a welded vessel, it can be welded again in a very short time. There are many other reasons why tank manufacturers should use the welding torch in preference to rivets. One of the most important is the fact that fittings of almost any nature can be attached in practically all positions with ease, allowing a much greater latitude in design and construction. Steel castings can be fused to cold-rolled shafting or other stock. Automobile or tractor frames and all forms of structural iron need have no limit as to design, because the various parts can be fused together at any desired angle. Fuel-tank, fender, pressed-steel wheel, rim, pulley and other problems confront most automotive engineers. Perhaps, in some instances, there are other means of joining members even better than oxyacetylene welding, but it can be stated with safety that this process covers a very wide and elastic range of applications.

The oxyacetylene welding process emphatically has not reached its height. While the present applications seem unlimited, there remain many problems that will tend to broaden the field when they are solved. Cast iron and aluminum are metals that are fused easily. In some instances the former may come out with a few hard spots or blowholes, but these nearly always can be traced to lack of heat. With aluminum, the heat conductivity of the metal and its expansion and contraction are subjects that may require study. Malleable iron presents a problem all its own; having been annealed, the question is how a part of the casting can be melted and again restored to an annealed state. At present a tough bronze is used to bond malleable iron; thus the anneal is not destroyed and a union results that usually is amply strong, provided a slight reinforcement is possible. Brass presents no difficulty if the correct filler-rod and flame are employed. This applies to copper and steel when they are cast, but when they are drawn or rolled the heat causes the molecules to expand and changes the nature of the metal surrounding the weld. A practical method of restoring this metal to its original condition should warrant consideration.

Recommended Practice

Since calling particular attention to certain necessary precautions that pertain to the welding of special metals results in the making of better and sounder welds, it is not amiss to dwell upon the welding of mild steel. Although steel is a very commonly used metal and one of the first to be welded, the fact remains that it is the most difficult to fuse successfully. Many welders think of steel as steel and that, if one kind of steel gives certain results under the influence of the welding flame, all steel will act in a like manner; but this is not the case. Separating the principal factors into the different classifications, in the order of their importance, first comes the human element, next the apparatus and then the filler-rods. More will depend upon the human element than upon anything else, for the welding plant itself will not do the welding, any more than a blacksmith's forge will produce chains, chisels, tongs or any other products; it is the "know-how" of the operator that produces results. Anyone might purchase a doctor's equipment, but this would not make him a doctor, because much schooling and experience are necessary; so it is with the welder, whom we might term a metal doctor.

In welding mild tank-steel there is much for the operator to take into consideration. The carbon content of the metal, the surface oxide or mill scale, the size of the welding tip, the adjustment of the flame and the size of the filler-rod all exert a direct influence upon the weld. The carbon content varies from 0.15 to 0.25 per cent in steel of this nature, and a tensile-strength of 52,000 to 60,000 lb. per sq. in. is required usually. As the amount of carbon is increased the welding naturally is rendered more difficult.

As steel in a molten state is very susceptible to changes, it should be held in that condition no longer than is absolutely necessary. Nitrogen and oxygen from the air will be absorbed by the melted metal. This reaction is increased greatly when the metal is overheated by using too large a tip. Usually this fault is found where an effort is being made to attain speed in welding. As the metal cools and contracts there is a natural tendency on the part of these gases to free themselves and small blowholes or pinholes will make their appearance. The metal is liable to be hard and brittle. If rewelding be found necessary, the metal will be subjected to the same treatment again and an added weakness is to be expected.

The correct size of tip depends upon the operator, for very few men obtain the same results even if the material and equipment are the same. Taking two welders, each working on test pieces cut from the same plate, the same

[1]Engineer, United States Welding Co., Minneapolis.

torch and tip being used, and gases from the same containers and the same grade of filler-rods being employed, we find that one specimen has about 50 per cent more ductility than the other in the vicinity of the weld. This confirms the importance of the human element. In accounting for this difference we examined the broken welds and found that the welds themselves had a flaky grain with all the characteristics of a casting, although not as uniformly, whereas the pieces that were welded were of rolled stock with a very fine close grain. At an intermediate space adjacent to the welds, the intense heat had caused the molecules of the original stock to separate and the grain became coarser. It is evident that a weld is a casting at best and that the longer the metal is kept in a heated condition the greater the effect mentioned will be, within certain limits. We can assume that one of the welds cited required a longer time to execute than the other. It is not therefore desirable under ordinary conditions to use a larger tip than necessary, but when a steel weld is made too rapidly, the grain limits will be very marked and narrow, in addition to the likelihood of the penetration not being thorough, indicating a weld with little ductility and one apt to crack after being placed in use. To obtain the best results these factors should be pointed out to the welders and each choose the size of tip that can be manipulated to the best advantage.

In welding most metals it seems sufficient to have what is termed a neutral flame, but in steel welding a much finer limit must be drawn. A common cause of faulty steel welds is the wrong kind of neutral flame. Neutral flames are sometimes soft, but generally they are very harsh. It is next to impossible to make a thoroughly satisfactory steel weld with a harsh flame. While it may be all right for building-up worn spots and the like, it has no place in working with the lighter sheet-metals. If it is used in the latter class of work, there will be not only a tendency to blow the molten metal away from the weld, but an overheating, which is indicated by the excessive sparks given off, is certain to occur. It is absolutely necessary that a soft neutral flame be used when making any kind of a steel weld; and, the softer the flame is, the easier it will be to effect a perfect fusion. A soft flame will not blow or overheat the metal. With a low-carbon steel, hardly any sparks should appear while a weld is being made; this is a criterion of whether an operator really knows his business. If sparks are in evidence, there are impurities in the piece being welded or the metal is being burned.

Steel Welding Apparatus

The apparatus plays an important part in steel welding. While there are many different makes of apparatus on the market today and all seem to function fairly well on most metals, there are few that give the adjustment required for steel welding. There should be a regulator on each line, one to control the acetylene and the other the oxygen. These regulators must be constructed so as to maintain an unvarying pressure in order that there will be no change in the welding flame while it is in operation. The welding torch should be designed to give a slow uniform delivery, at the tip, of the gases that have been thoroughly mixed. This will permit complete combustion of the gases. No unburned gases can enter the weld then, and the preheating flame of hydrogen that envelops the neutral flame will exclude the air and protect the weld so that it will be possible to convey a small clear pool of molten steel along the seam. The desired results can be obtained with and greater efficiency will follow the use of the equipment described.

Some welding torches employ the injector or semi-injector principle in which the oxygen as it is forced through a very fine opening under a rather high pressure is relied upon to draw in the acetylene under a lower pressure. These torches may be satisfactory on some classes of work, but they are not recommended for steel work. In nearly every instance a slightly oxidizing flame can be noticed with such torches which, instead of improving after they have been in service for a time, become worse on account of small particles of dirt lodging in the fine oxygen passages. This necessitates still higher pressures on the oxygen line to force the needed volume of gas through. Cleaning this type of torch occasionally will help to some extent in keeping the oxygen pressure down as low as possible. It is well to remember, however, that excess oxygen is the welder's worst enemy; hence, the lower this pressure can be kept, the better it is for the weld and the welder.

Filler-Rods

In choosing filler-rods freedom from impurities and a low carbon-content are the main considerations. The size has a direct relation to the flame size. If the rod is too small it will burn usually; if it is too large, it will not fuse with the metal that is being welded and probably will have a tendency to stick. When introducing the filler-rod, the flame should come into direct contact with it as little as possible. It is desirable to melt the end of the filler-rod in the molten metal rather than by the flame, as there is less chance of changing its character.

When making ripple welds on pressure vessels, it is necessary for the operator to hold the tip at the correct angle and have the flame adjusted so that a small pool of clean melted metal will be carried along the seam. Constant watching is required to see that each side of the weld is thoroughly fused; penetration must be complete and the filler-rod added to give slight reinforcement, so that the resulting weld will be about three times as wide as the metal is thick.

Focusing attention on the human element to see what steps can be taken to insure the greatest efficiency, by testing welds periodically and publishing the results an esprit de corps can be built up among the welders in a large shop that will encourage all concerned and certainly assist in producing better results. In testing it is necessary to break the weld so that the interior can be inspected for penetration, adhesion and oxidation, because a weld must be more than skin deep and the nature of the interior seldom can be determined from outside appearances.

THE DISCUSSION

C. S. Moody:—During the war our welders complained of having difficulty with their filler-rods in that the metal came off in chunks. They did not seem to be able to produce good work. Examining a good and a poor filler-rod for test, I found that one was high and the other low in carbon, the good one being low in carbon. After some difficulty we obtained the low-carbon filler-rods we wanted, but had trouble again.

Lorn Campbell, Jr.:—If the filler-rod metal came off in chunks, this was no doubt due to impurities in the rods.

Mr. Moody:—We made an investigation and determined that the condition of the carbon in the rod has a good deal to do with the matter; by heat-treatment we made good welding rods out of the higher-carbon poor material. Further, we made good welding rods out of poor low-carbon or practically carbonless rod by suitable

heat-treating. We salvaged a great quantity of material in this way.

MR. CAMPBELL:—Before the war practically all of our welding rods were imported. They were called Norway or Swedish rods. It is very common now to have people call for Norway iron in the welding industry. During the war none was supplied. The American product has been refined to such an extent that it approaches the Swedish iron very closely, but it does not equal it.

Steel welding is very difficult; very few welders can weld steel thoroughly. The best way to test a welder's ability is to give him two pieces of plate about ½ in. thick and say 4 in. wide, have him make a fusion from one side and then break it on the anvil through the weld in any direction. It is immaterial whether one side or the other is broken. Invariably, it will be found that the weld has penetrated only one-half of the way through. It is difficult to say whether that is due to defective vision or what causes it. Some welders will swear that they have their flame in contact with the metal when in reality they are holding it about 1 in. away. The steel or the metal may increase in size as we know it does when it is heated to the melting point, and they may think they are completely through when in reality they are only one-half of the way. Much depends upon filler-rods. They are the cheapest part of the weld. With a difference of a few cents in the cost of filler-rods one is almost warranted in purchasing the finest filler-rods possible.

A MEMBER:—I have never heard anyone else make a distinction between neutral flames. How do you define a soft neutral flame?

MR. CAMPBELL:—Neutral flame is a term used in welding. It refers to theoretically equal parts of oxygen and acetylene. We find it necessary to add one part of oxygen to one of acetylene, the gases combining while passing through the pipe-lines. The additional oxygen is taken from the air. Most torches require slightly more oxygen than acetylene. As manufacturers, we are called upon frequently to specify the gas consumption of various sizes of tips, so that costs can be computed accurately. The different sizes are distinguished numerically. A typical question is, "How much gas does a No. 6 tip consume in a given period?" We can make that tip consume almost any amount of gas desired, with a short or with a long flame. In the welding of most metals it does not matter much whether a long or a short flame is used but in steel welding careful adjustment of the flame is necessary in order not to injure the steel when it is melted. If the flame has a hissing sound it is harsh, but it is still a neutral flame. In steel welding we need a soft neutral flame of ordinary length. If that is not giving enough heat, a larger size of tip must be used and the length of the flame cut down. In all cases the flame should be soft and give no sparks when working on steel. Sparks mean that there is burning metal or that there are a great many impurities. A good welder will recognize this condition instantly.

A MEMBER:—Do I understand correctly that a soft flame is caused by reducing the pressure and increasing the size of the tip?

MR. CAMPBELL:—Yes; the heat of the flame is the same but the flame length varies.

A MEMBER:—Is it more difficult to weld steel from one side?

MR. CAMPBELL:—It is desirable to do so.

A MEMBER:—For what reason?

MR. CAMPBELL:—The longer the steel is subjected to the action of the flame, the greater is the chance of burning it. If the weld is made from one side and it is done thoroughly, time and gas are saved and a better fusion is made.

A MEMBER:—It has been my practice to weld on both sides. I learned to do this myself. I thought there was less gas used because of the smaller cross-section to be filled in.

MR. CAMPELL:—Welding a ½-in. steel plate from one side and reinforcing, all in one operation, is perfectly possible and it is being done continually. There is no need to go over a steel weld a second time; in fact, a steel weld should be fused thoroughly the first time. It is well, however, in such cases to find the places where there will be strains and to anneal the ends of the pieces first, as that aids materially, and then bring them to a red heat slowly with some form of preheating apparatus before bringing the welding torch into use and actually commencing the welding operation.

MR. MOODY:—What are the relative merits and demerits of oxyacetylene and oxyhydrogen methods of welding?

MR. CAMPBELL:—A comparison is hardly possible. Oxyhydrogen welding is limited to thinner materials; oxyacetylene welding can be used with both thin and thick metals. We have executed welding jobs within the last year in which we have added over 600 lb. of cast-iron filler-rods in making large welds. The oxyhydrogen flame has a much lower temperature and is used extensively for cutting. It is very valuable because it makes a smoother cut, will cut faster and is much superior to the oxyacetylene flame for that purpose, in many instances.

MR. MOODY:—In places where it can be used, does it not make a more perfect weld than the oxyacetylene flame? With the oxyacetylene flame nitrogen is put into the weld, but that is not done by the oxyhydrogen flame. The nitrates introduced when welding with oxyacetylene form a needle-like structure that causes brittleness. The hydrogen flame is used on metals that become oxidized readily.

MR. CAMPBELL:—The oxyhydrogen flame is used in handling aluminum ware and in one or two instances in welding very thin steel-plate, but otherwise it is not used very much. The amount of nitrogen entering an oxyacetylene weld is extremely small and generally is disregarded.

D. W. ONAN:—What method is used to keep a thin plate from buckling?

MR. CAMPBELL:—It is usually clamped with angle-irons.

MR. ONAN:—Is there no other practical way of guarding against this distortion?

MR. CAMPBELL:—No; except that an allowance is made for the buckling. In making a steel weld along a seam, ordinarily ¼ in. per ft. should be left to allow for contraction; otherwise there will be overlapping and buckling.

Aberdeen Proving Ground Visit

PROBABLY not since the days of the war have the members of the Society experienced the sensations that were theirs on their visit to Aberdeen Proving Ground on Oct. 7, by invitation of General C. C. Williams, chief of Ordnance. There was a strongly reminiscent feeling of the time when nothing mattered but the production of the tools for making war and when anything less than 24 hr. a day on the job was considered in the light of a vacation.

On arrival, the visitors, including over 200 Society members, were met at the Aberdeen Station by the Proving Ground train and taken at once to the range where the 16-in. 50-caliber gun was fired. This gun, having a range of over 30 miles, can outshoot any gun on any ship in any navy. After a group photograph had been taken of the visitors, the program was continued by the firing of various smaller-caliber guns and by an inspection of a number of types of aircraft and of American and foreign aerial bombs, including the monster 2-ton bomb recently developed. Bombs were later dropped from airplanes both into water and on land. One of the most interesting demonstrations was the use against small free balloons of tracer ammunition from machine-guns, by which it was possible to visually follow the flight of the bullets from the gun to the target.

In the afternoon an automotive apparatus circus was of particular interest to the members of the Society since it presented a number of types of motor-driven vehicle, including large and small tanks and numerous caterpillar tractors and gun-mounts, one of which displayed remarkable speed and flexibility of control. An inspection was made of mobile ordnance repair-shops, and in the evening a demonstration was given of a newly developed flashless powder that will make it much more difficult to ascertain the location of guns by their flash.

The thanks of the Society are due to the Ordnance officers who planned and carried out the remarkably comprehensive and exceedingly interesting program with much precision. Each demonstration was carefully described immediately before it actually took place. There was scarcely a moment throughout the entire day unfilled with some event of interest.

Not the least diverting part of the visit to Aberdeen was the journey by motor-bus of over 20 members of the Metropolitan Section who left New York City on Thursday morning and arrived at seven in the evening at Wilmington, Del., where they spent the night, reaching the Proving Ground after a 2-hr. run on Friday morning. While the cost to the members who traveled by this bus was limited to their hotel bills, through the courtesy of the International Motor Co. in providing the bus, an analysis of the actual cost of transportation, including the items of gasoline, oil, depreciation and driver's wages

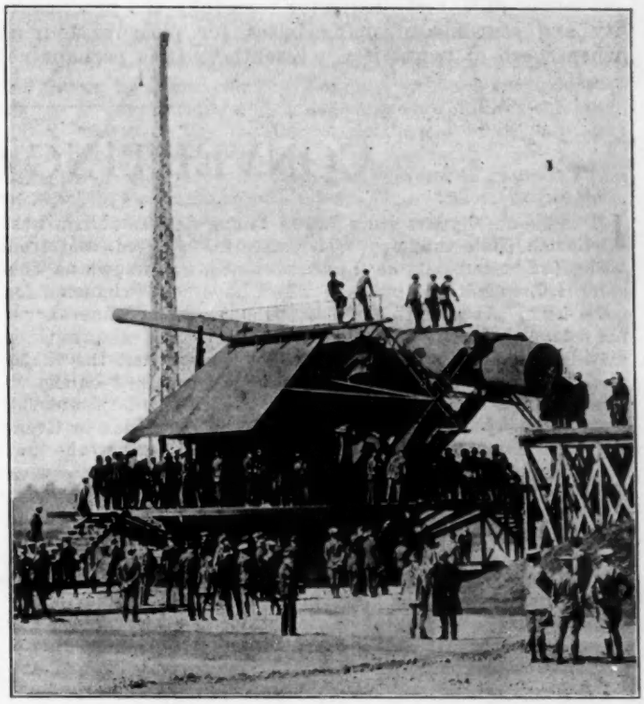


Photo by International

MEMBERS OF THE SOCIETY INSPECTING THE NEW 16-IN. 50-CALIBER GUN THAT IS MOUNTED ON A DISAPPEARING CARRIAGE AND HURLS A 2400-LB. PROJECTILE APPROXIMATELY 22 MILES

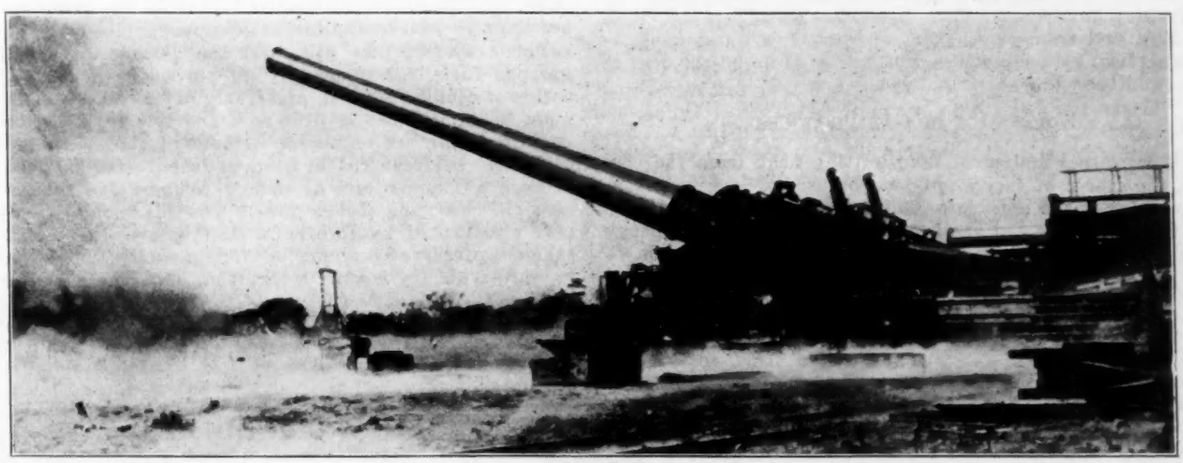


Photo by International

A NEW 16-IN. GUN ON A RAILROAD MOUNT BEING FIRED

and expenses, showed a figure of slightly over 1 cent per passenger-mile with the bus fully loaded. This is in marked contrast to the present rate of railroad transportation, which is in the neighborhood of 4 cents per passenger-mile, and illustrates forcefully the practicability and economy of using buses for pleasure touring when speed of travel is not essential. It is perhaps not too much to say that the term "pleasure car" that has been so erroneously applied to the passenger car may well be used in the near future to describe a type of vehicle which can carry a moderately large party of people over good highways, past attractive scenery, in comfort, cleanliness and at a cost of possibly one-third of the railroad fare.

CONVERTING COAL INTO GAS

IT is about 70 years since James Young first established the Scotch shale industry. The material he used, and from which the best results have been obtained, was known as Torbane Hill shale, the supplies of which have been exhausted for some time. As a matter of fact, this particular mineral was not a true shale, but actually a cannel coal. The mineral when distilled yielded about 125 gal. of oil per ton, but the shales distilled since its exhaustion, which are obtained chiefly in Midlothian and Llinlithgow, are not so rich in oil-content. A large quantity of shale exists in different localities in Great Britain, some yielding on the average about 50 gal. to the ton; but, unfortunately, the oil obtained has a high percentage of sulphur in its composition, and so is practically useless. So far, this oil cannot be purified by any of the usual methods.

Coal Tar a Source of Oil

A source from which large quantities of oil are forthcoming is ordinary coal tar, which, as obtained at the ordinary gas works from the carbonization of bituminous coal, is an extremely complex mixture of carbon, hydrogen, nitrogen and other elements. When tar is subjected to distillation, the light hydrocarbons are the first to come over, followed by heavy oils and tar oils, all of which are in great demand. It seems probable that coal will, in the future, be regarded as a great source of oil supply. The time is coming when we shall be unable to afford the transport facilities for moving coal on congested railroads. We shall not be able to afford or obtain the labor to perform the arduous work of handling solid fuel and clearing and removing ashes from furnaces and grates. Solid fuel must gradually die out for marine work, oil fuel taking its place, and locomotives also will be fired with liquid fuel, in which term is included the colloidal mixtures of solid and liquid fuels. At present it seems impossible to think of liquid fuel as a general means of supplying heat and power, nor can the generation and transmission of power by electrical means be considered as meeting the requirements for the provision of heat for general and industrial needs. Its average heat-efficiency today does not equal 10 per cent, and although it is certain that this figure can be improved upon it will certainly be many years before it reaches as high as even 20 per cent, and from every point of view it is unthinkable to transmit heat by a method in which from 80 to 90 per cent of the actual heat value is lost.

Advantage of Gas Producer

The one other source of transmitting heat from the coal mine, the source of fuel supply, to the user of gas, is in converting coal at the mine into liquid and gaseous fuel. Liquid fuel will be recognized as the medium for providing energy for all transport by land, sea and air, with the exception of electrical transport for congested areas, while gaseous fuel will be used direct for most heating purposes and for the generation of electricity by either internal-combustion or steam-driven engines.

There are several advantages in the use of gas producers, chief of which are that a poor quality of fuel can be used with good results; that the capital and operating costs of the plant are low and that high returns can be made by the recovery of the ammonia formed in them from the nitrogen in the coal. It appears, however, that the tar oils obtained from their working are not valuable, the condition in which they come from the plant is such that it is difficult to work them up, and in the opinion of tar distillers the final products compare far from favorably with those obtained from other methods of effecting the destructive distillation of coal. Now that all qualities of fuel have increased so greatly in price, and low-grade fuels have risen in cost in a far greater proportion than have other and better qualities, there is not the same saving that there is in the use of producers.

The Principle of Total Gasification

Low-temperature carbonization, on the face of it, should be a simple process. Many of the difficulties of high-temperature working are absent, but of course, there are others incidental to the process. Coking coal at low temperature swells and becomes gummy, and it is not the easiest of matters to get the sticky friable mass to leave the vessel. Still, on the assumption that the difficulties can be overcome and the process worked satisfactorily, the resultant tar oils are high in quality and quantity. There is, however, a residue of solid fuel, though producers convert it satisfactorily into gas to enable a further proportion of the ammonia to be recovered. The principle of total gasification is the partial carbonization of coal in a vertical retort superposed on a water-gas generator, the retort being heated externally by the products of combustion of the producer during the "blow" period, and internally by passing the water-gas made up through the charge in the retort. The plants are built in duplicate, and the gaseous products are passed up one plant and down the other for the purpose of fixing all the hydrocarbons and retaining them as gas. The great detraction from the national value of the process is that it yields no tar oil, while by fixing the gas, ammonia as well as the tar, is destroyed.

For a system that will meet the demand for liquid and gaseous fuels, for practically all purposes, the total gasification of coal is essential, preferably in one vessel. The plant must be economical in first cost and low in labor charges, but, above all, the maximum amount of the volatiles in the coal must be recovered in a liquid form, being distilled over in such a manner and at such a temperature that a minimum of "cracking" takes place. The gas should be stripped of all saturated hydrocarbons, and special care should be taken to preserve all ammonia. The plant should be designed to work with any coal of a far from uniform character over short periods.—*Oil News.*

MOTORIZED STOCK FARM

THE most completely motorized farm that we have found in the corn belt is located in Lake county, Illinois. It is not what would be considered a typical corn-belt farm; rather it is a live-stock farm, for all the crops grown are fed on the farm. As this farm comprises 3500 acres it is evident that a large amount of live-stock is kept. Approximately 2100 acres is in crops, and 1000 acres in woods and permanent pasture.

In spite of the fact that the horse is fully appreciated he has had to yield a large part of his domain on this farm to the tractor, truck and automobile. The horse is not entirely displaced; far from that, for the manager believes that it is not practicable to dispense with his services entirely; but the equine motor has been oriented into his place judged by the rigid standard of operating expenses. The tractor is used on this farm because for certain work the operating expenses are lower, and in his sphere the horse is used for the same reason. There may be other farms in the corn belt where as many crop-acres are grown per horse as on Hawthorn Farm, but we have never visited a farm where as many and varied operations were performed with the tractor nor where the tractor was used as many hours per year.

This year the crops grown consist of 700 acres of small grains, 677 acres of corn and 703 acres of hay. The field work starts about the middle of March. As soon as the ground is in condition the seeding of the small grain starts. The outfit consists of four tractors each pulling a 10-ft. double disc, two tractors each pulling two 8-ft. grain drills, two motor cultivators each pulling a 25-ft. spike-toothed harrow. If the ground has been fall-plowed it is double-disced once, but if the small grain is to be seeded on corn ground which has not been plowed it is double-disced twice. The ground is first disced, then seeded and crossed with the spike-toothed harrow. This crossing is done to break up the corn-stalks more effectively. The grain is hauled to the field with horses. To reduce the number of stops when seeding the boxes on the drills have been enlarged to twice the normal size.

Two men are required on each drilling outfit, one to drive the tractor and the other to watch the drills. Markers are used to guide the driver of the tractor on the drilling outfit. Careful checks showed that where horse-drawn drills were used it was not unusual to find that as much as 5 per cent of the area had been missed. With the tractor this skipping has been practically eliminated. In the past four years seeding operations have not been delayed because the tractor was being used nor have any ill effects from packing been observed. In fact this year the grain was taller in the tracks of the tractor.

The next operation is corn-planting. The corn ground is all fall-plowed. It is double-disced once with the tractor and harrowed and planked with the horses. Planting is done with a four-row machine operated by one wire and drawn by the motor cultivator. This planting outfit was made by an ingenious combination of two two-row planters. The checking is not as accurate as could be wished but is as good as has previously been done with the horse planters. This outfit was experimented with last year and used to plant the entire crop this year. The manager believes that its work can be improved in the future. The corn is harrowed before it comes up. Sometimes this harrowing is done with the motor cultivators, sometimes with horses, and again with both depending upon the developments in other farm work.

The corn is cultivated an average of six times. Three motor cultivators do the work following the rows, and 11 single-row horse-drawn cultivators are used for crossing. The three motor cultivators cover as much ground as the 11 horse-drawn outfits, but the manager is not yet convinced that the motor cultivator can be used successfully in crossing. As cultivating is the determining factor in regard to the number of work-horses required, an effort is to be made to improve the checking of the corn so that the two-row motor cultivator can be used in cross cultivation.

The harvesting of the first crop of alfalfa starts before corn cultivation is finished. One tractor with three mowers behind it can cut 35 acres per day. Only one man is used on this outfit. The first crop of alfalfa is unusually heavy. In raking one tractor pulls two side-delivery rakes. For the second cutting one tractor pulls four of these rakes. The hay is gathered with hay-loaders. One tractor pulls two wagons and two loaders. The hay-fork is operated with a drum driven by a gas engine. The hauling from the field to the barn is done with tractors, each machine pulling a train of three wagons. The number of tractors used in hauling depends upon the distance.

This same system of hauling and equipment is used for hay, shock grain, manure and corn. When the management decided to concentrate the live-stock plants it was recognized that hauling would be a big problem. The solution decided upon was to pull a train of three wagons behind one tractor, thus enabling one man to move a large tonnage. This system has worked well. The method of assembling or breaking up a train is interesting. A team of horses is attached to a light two-wheeled truck. On the back of this truck there is a hook that can be attached quickly to the end of the stub tongue on the wagon. The same type of hook is used on the back of each wagon. When a wagon is loaded the snap team draws it up in a diagonal position with reference to the wagon it is to be hitched behind. The men who do this work have become so expert that the wagon can be stopped in such position that the connection is easily made. In breaking up a train the same equipment is used. The number of tractors used for hauling on any operation depends upon the length of the haul.

In some seasons the second crop of alfalfa is ready to put up as soon as the first has been harvested. In any case harvesting starts before the haying is finished. Three outfits are put in the harvest field. There are two 15-27 tractors, each pulling two 8-ft.-binders, and a motor cultivator pushing one 8-ft.-binder. Each of the larger outfits is operated with two men. The motor-cultivator outfit is used for opening up the fields, cutting off the corners, etc. When not at these jobs it is used in regular cutting. The mechanical shocker has been tried but abandoned.

The threshing is done with a 40 x 64 machine. A shock loader pulled by a tractor is used for loading the grain in the field. The wagons are hauled to the thresher by the tractors, where the snap teams take them up to the self-feeder. No men are used on the straw stack. The grain is run into the wagon boxes and unloaded with an elevator. The shock loader, elevator and absence of men on the straw stack were innovations introduced this year. The shock loader eliminated the use of seven men, the grain elevator seven and the method of stacking the straw three. The manager stated that the saving on the labor bill will pay for the new equipment this year. In addition to this a tractor was released from the threshing work and set to plowing.

With the threshing out of the way the next operation is hauling manure. The wagons are loaded in the yard by five pitchers, drawn out with snap teams and coupled into trains. The tractors are used to draw these trains to the field. Here, the manure is transferred by a ditch-filler and tractor to spreaders, which are operated by horses. Three tractors hauling and one unloading kept four spreaders busy at a distance of 1 mile from the yard. If the haul is shorter fewer tractors are used; if longer, more.

Mechanical Manure-loader Needed

A mechanical manure-loader is much needed. When a successful one is secured one man will do the loading which now requires five. Some objections might be raised to this method, because the manure is handled twice, but this is more than offset by the time saved in hauling. Each wagon makes from two to three spreader loads, and the transfer is made with little loss of time. It averages about 2 min. per load. If it is possible to secure a loader the manure will be transferred from the yard to the field without being touched with a fork.

Silo-filling is carried on in accordance with the scale on

which other work is done. Two binders, each pulled by a tractor, are used to cut the corn. Elevators are attached to these binders. A tractor pulls the wagons alongside and the train is loaded. It requires 4 tractors and 12 wagons to get the corn from the field to silo, where it is run through a 15-in. filler operated by one of the big tractors. Over 200 tons of silage per day can be put up with this outfit.

With the silo-filling out of the way the chief interest centers on the fall plowing. There are about 1000 acres of this to be done. Each 15-27 tractor with a three-bottom plow can turn about 8 acres per day. The corn which is not put in the silo is picked by machinery in the field. A tractor is used to pull the picker, but as fall plowing is on at this time the corn is hauled to the crib with horses. The picker will gather 18 double wagon-box loads per day.

The tractors are used almost continuously from the middle of March until the middle of December. Very little time is lost on account of breakdowns. The manager estimated that the 15-27 tractors were used approximately 200 days per year.—E. A. White in *Farm Implement News.*

AUTOMOBILE BUILDING IN ENGLAND

MASS production is an expression constantly on the lips of English shop managers. This is understood to be an American phrase or, at least, an American principle, though I do not remember having heard the term used here. The idea is plain enough to understand. It is that of making the product in a sufficiently large mass to take advantage of the latest and most refined production methods for the sake of reducing the cost to the lowest possible figure. Some English automobile shops have been reorganized on this basis, and the most successful of them would produce an output that would be fairly appalling there if they were running full-time and full-force on the plans for which they were laid out. The output would not, of course, be appalling in America. It is said that the number of automobiles licensed in New York City alone exceeds the total of all the British Isles; and the field occupied by the medium or low-priced car here is taken care of there by the motorcycle with side-car, which is the ordinary man's means of conveyance.

Automobile builders in England have been looking to export trade as an outlet for the increased products of this "mass production." This offers no immediate prospect of success, however, owing to their inability to compete with American firms who are at a considerable advantage due to the greatly increased cost of material in England and to the fact that wages are, in many cases, now on a parity with those of America instead of being considerably below as in years past. This, added to the lower production capacity of the English workman, seems to make competition hopeless for the near future, at least in the markets of the world. The ability and willingness to do the highest grade of body-finishing and upholstering still survives in England to the extent that the stock cars of the best makers bear comparison with the finest product of the various factories in the United States producing custom-built bodies.

It seems that the great prizes in automobile production in England and France will go to the builder of the first-class car who is willing to study the following points carefully:

(1) Making such changes in the design as will facilitate the construction of the car without affecting its quality in any degree. A great improvement in this respect can be made in practically all high-grade cars

(2) Developing the ability to rough-machine the parts as rapidly as is done by the producers of the cheaper grades of car, while maintaining the fine finish and fitting in the final operation. This is difficult but possible

(3) Making a study of the possibilities of machine-finishing of parts where hand-work is now the rule. This applies to many surfaces where hand-work is of no advantage but costs more and is employed only out of deference to the tradition as to the excellence of hand-work in itself

(4) Making sure that the body-work and upholstering in general is done as finely as at present, and that the finished car will suffer in no degree whatever from the improvements in design and manufacture mentioned

(5) Specializing on one design of chassis. The builder who is willing to do this, can carry out all the previously mentioned points to a much more successful extent than the one who carries two or three designs. It should be possible to specialize without injuring the quality of the product in any way

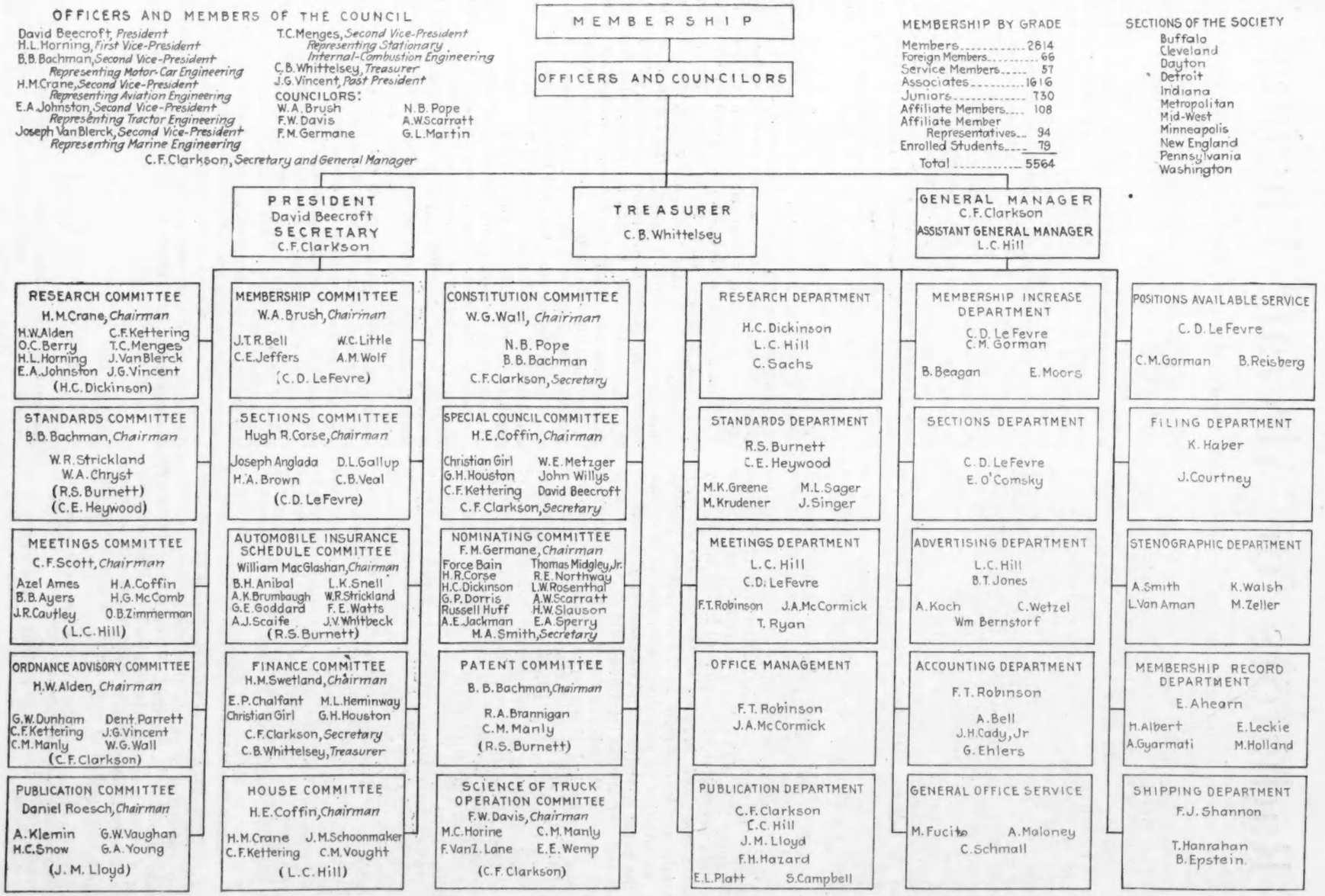
In America the producer who can build a car of fair quality in enormous quantity has an opportunity to make engineering skill reap the highest reward. In Europe the man who succeeds in solving the problem of design and construction for the very high-grade car, made in moderate quantities, will be the one reaping the largest financial reward.—R. E. Flanders in *Machinery.*

PATENTS

IN a year about 90,000 applications for United States patents are filed, of which about 35,000 come to issue. Counting the time of all the people involved as well as the money spent in fees and experiments, $100,000,000 per annum is a conservative estimate of the country's expenditure. And over 90 per cent of it is wasted.

Thousands of patents are procured for half-baked ideas doomed to failure. And strange as it may seem this phenomenon is not without its good results. It follows natural laws. Nature is prolific. Thousands of seeds are produced in order that a few may survive. Now and then the germ of a great idea is to be found in a half-baked invention. Most startlingly new ideas come from the rank outsiders anyway. Those entrenched in a particular field become cautious and conservative; they know the pitfalls, whereas an outsider is often the "fool who enters where angels fear to tread," and once in a while gets away with it.

It seems a pity that so much energy and money are wasted on inventions and patents when by the application of a few simple principles most of it could be saved. This would also result in giving inventions of true merit a better chance for a hearing, instead of overwhelming them by the general ill-repute of the others. The tantalizing part of it all is that there remains a tremendous field for invention as most of the arts are still in their infancy.—E. Scheyer in *American Machinist.*



STAFF AND INTERNAL COMMITTEE ORGANIZATION OF THE SOCIETY OF AUTOMOTIVE ENGINEERS, INC.

Radiators for Aircraft Engines[1]

By S. R. Parsons[2] and D. R. Harper, 3rd[3]

In a technological paper bearing the above title, the National Bureau of Standards communicates much material which it hopes will prove of value to the automotive industry, as well as of interest to physicists and engineers generally. The paper describes the laboratory investigations relating to aircraft-engine radiators which were conducted by the bureau during the war and in the two years immediately succeeding it. Individual reports covering many phases of the subject have been published previously in the technical series of the National Advisory Committee for Aeronautics and in scientific and engineering journals. These reports, however, lack the systematic coordination, uniform terminology and unified mathematical treatment which would characterize a handbook on the subject. Moreover, later work threw much additional light upon matters not settled at the time of publication of the early reports. The present paper is a complete revision and recompilation of the material available.

The special investigations reported included development of the methods of measuring airflow in radiator tubes; experiments upon the effect of nature of surface upon airflow and upon heat dissipation from the surface of metal tubes to a high-velocity airstream; experiments to ascertain the degree of turbulence in the air-tubes of a radiator core; and mapping of temperature distribution, axially and transversely, in the air-tubes of radiator cores. In addition to recording these special investigations, the paper contains a full description of laboratory methods and instruments for those tests of radiator cores properly made in the laboratory, of both physical properties and geometrical characteristics such as size and shape of air-tubes and of water-tubes.

The work included laboratory measurements of cooling power, head-resistance and geometrical characteristics of over 100 types of radiator core. These data are tabulated in an appendix and the performance characteristics of 66 types of core are given in graphical form. The general conclusions from these measurements and from the special laboratory experiments already mentioned are incorporated in an exposition of the fundamental relations between the conditions under which a radiator operates, its characteristics of form and construction and the properties which describe its performance. This portion of the designer's field is by no means the whole, however, and the paper does not treat the important considerations of sturdiness, ease of construction and repair, cost, form of design imposed by the structure of the aircraft and the like.

Heat Dissipating Power of Cores

The heat-dissipating power of a given type of core construction was found to be specified completely when the mass rate of airflow is specified. It makes no difference whether a given mass rate is obtained by high velocity and low density or low velocity and high density, a relation which was studied in some detail because of its significance in respect to behavior of aircraft radiators at great altitudes of flight. The empirical relation

$$H = bM^nT$$

where H is heat dissipated per unit time per unit frontal area of core, M is mass of air per unit area per unit time through the air-tubes of the core and T is difference between the average temperature of the water in the radiator and the temperature of the air at entrance to the core, was found to hold for all ordinary types of core construction, b and n being constants pertaining to any particular core. The numerical value of n was usually in the neighborhood of 0.8, indicating that the relationship between heat dissipation and air-flow through the core of a radiator is not far from the relationship of direct proportionality, although too far to assume such a relation over any considerable range of air-flows.

A second equation for computing the cooling power of a core is

$$H = C_pMT\ (1 - e^{-\alpha x_1})$$

where H, M and T have the significance quoted in the preceding paragraph, e is the logarithmic base 2.718, C_p is specific heat of air at constant pressure, x_1 is the depth of the radiator core, a dimension parallel to air-flow, and α is a constant for a given core and given airflow through it. Since a chosen value for α permits no latitude in airflow or in changing core construction, the equation in this form is intended primarily for study of the effect upon cooling power of changing the depth of core. Giving due consideration to head resistance as a function of frontal area and depth, the formula permits computation of the optimum depth of radiator for given conditions. For very high-speed flight, it is advantageous to use cores much deeper than was the common practice in the early days of airplane development, 8 to 10 or 12 in. of depth being desirable for some types of the usual ¼ to ½-in. air-tube core in unobstructed positions.

The formula just quoted is not entirely empirical in its origin, but has a rational basis. The assumptions underlying it are plausible and it is not surprising to find that in applying it to results of measurements with almost all common types of core these results are represented very well. The parameter α is an abbreviation for pq/MC_p, where M and C_p have their former significance; p is total perimeter of the air-tubes in unit frontal area, provided the cooling surface is all direct surface, and an equivalent value for the cases where part is indirect cooling surface; q is the cooling coefficient between the metal and an airstream of velocity corresponding to M, namely, q is heat transferred per unit time per unit area of metal per degree temperature difference between the metal and the air flowing past it. The numerical values of q were found to agree very well with values computed from a formula given by Stanton and Lanchester,

$$q = \frac{C_pR_f}{V}$$

and by Lees,

$$R_f = \rho V^2\left[0.0765\left(\frac{\mu}{V\rho D}\right)^{0.35} + 0.0009\right]$$

the comparison being made for radiator cores with smooth round and square and hexagonal air-tubes, nearly all direct cooling surface. The formulas given

[1] Abstract of an official publication of the Bureau of Standards, Washington; communicated with the permission of the Director of the Bureau of Standards.

[2] Assistant professor of physics, University of Michigan, Ann Arbor, Mich.

[3] Physicist, Bureau of Standards, Washington.

were originally stated for long circular cylindrical tubes with smooth walls, C_p being specific heat of air at constant pressure, V the velocity of the air through the tube, ρ its density and μ its viscosity. R_f is the surface friction, or force per unit surface between the airstream and walls of the tube, and D is tube diameter.

The foregoing formulas can be combined into a single expression, making some reductions not given here in detail, so as to compute heat dissipation of a core from its dimensions. For the simple type of regular cellular cores, it seems highly probable that results will be reliable within 10 per cent.

$$H = MC_pT(1 - e^{-\alpha x_1})$$

$$\alpha x_1 = \frac{x_1}{r}\left[0.0471\left(\frac{a\mu}{rM}\right)^{0.35} + 0.0009\right].$$

where

H = heat dissipated, in units of power per unit frontal area of core
M = mass of air per unit time per unit frontal area
C_p = specific heat of air at constant pressure
T = temperature difference of the water and air entering the core

Any consistent set of units whatever can be used for the above four quantities, but care must be exercised to avoid any inconsistencies; that is, the heat units for H and C_p must match, and so must the mass units for M and C_p, the area unit for H and M, and the like.

One consistent set of units in English measure would be as follows:

H = British thermal units per second per square foot of frontal area
MC_p = Pounds per second per square foot, multiplied by the number of British thermal units per pound per degree fahrenheit
T = Degrees fahrenheit
x = Feet
r = Feet
a = A ratio, in any units such as square feet per square foot of frontal area, or, mass pounds per foot per second
M = Mass pounds per square foot per second

The same is true for the following sets of quantities, although the units for these need not be the same as the first set.

x_1 = depth of radiator core, in the same units as those of r
r = hydraulic radius of air-tube, the quotient of area divided by perimeter
M = mass of air per unit time per unit frontal area
μ = viscosity of air in a unit consistent with M and r
a = free area of core; the ratio of the total cross-section of the tubes to the frontal area. Because it is a ratio, it is independent of units

Laboratory Measurements

The laboratory measurements of heat-dissipating power were made with two sources of heat, steam and hot water. For superheated steam, the effective temperature is computed by weighting properly the heat derived in each stage, such as loss of superheat, condensation and the cooling of the water, according to the formula:

$$T_m = \frac{\left(T_c + \frac{S}{2}\right)C_pS + T_cL}{C_pS + L}$$

where T_m is mean effective temperature, T_c is temperature of condensation, S is superheat in degrees, L is latent heat of condensation, and C_p is the specific heat of superheated steam. The condensate was usually not cooled significantly below the temperature of condensation and the formula given above is in the simplified form resulting from neglecting such cooling. An intercomparison of test data on 10 cores using both superheated steam and hot water as sources of heat for the calorimetric measurements showed that no appreciable difference existed between the results obtained by the two methods. A series of measurements using water as the source of heat were made with the rate of waterflow varying over a wide range. As might be expected, a wide range of variation of heat dissipation occurred with change of rate of waterflow when the rates were extremely low, but at the rates of flow common in radiator use the effect was not significant. It seems safe to assume that heat dissipation for conditions all constant except rate of waterflow will attain a value within 5 per cent of the maximum which it will reach with any rate of flow, if the rate be as much as 3 gal. per min. per in. depth of core 1 ft. wide. This flow is well within the margin of circulation found in most aircraft cooling systems.

The effectiveness of indirect cooling surface, namely, cooling surface not backed by flowing water, is considered in detail and the mathematical relations are developed which describe its behavior. The effectiveness of indirect surface is defined as the ratio of its heat-dissipating power to that of an equal area of direct cooling surface all at the temperature of the edge of the indirect surface which has contact with the source of heat. For long narrow fins such as the indirect cooling surface found in a square cell or hexagonal cell construction, the effectiveness is

$$E = \frac{\tan hU}{U}$$

where U takes the form

$$U = b\sqrt{\frac{2q}{yk}}$$

in which b is the width of fin where good thermal contact occurs along one edge of the fin only, and is one-half the fin width where good thermal contact is made by both parallel edges. A good thermal contact means soldered or integral metal. Mere contact, unsoldered, of two pieces of metal is thermally a discontinuity. The fin thickness is y and the thermal conductivity k, the quantity q being the surface heat-dissipation coefficient in units consistent with k and the dimensions b and y. If K be expressed in British thermal units per minute per square foot per degree fahrenheit per foot, and b and y be each expressed in feet, then q must be British thermal units per minute per square foot of surface per degree fahrenheit temperature-difference between the metal and the air. For the combinations of values usually occurring in radiator practice, the effectiveness exceeds 70 per cent and commonly averages 85 to 95 per cent. The formula was applied to calculate optimum dimensions for fins under various conditions, the results being tabulated. The equations of thermal conduction are also used to compute a table of temperature-drop through water-tube walls of various thicknesses and materials.

Details on Miscellaneous Topics

A considerable amount of detail not suited to abstracting is to be found in short notes on such topics as effect of yaw on performance, slipstream mountings, wing radiators, shuttering, radiator requirements at altitude and methods of computing performance at altitude from test data obtained at ground level. A brief treat-

ment is included of the subjects of partially streamlined casings to enclose a radiator, and of nose mounting.

From the viewpoint of an airplane designer it is desirable to specify radiator performance in terms of flying speed of the plane. In general, this cannot be done directly because too many factors are involved in the relation between flying speed and the airflow through the radiator core. It becomes necessary, therefore, for describing characteristics of the radiator, to adopt airflow through the core as the prime variable, there being no other quantity or entity available for the purpose. The ease or difficulty of applying such a description of performance to plane design rests then with the difficulty in estimating the probable airflow through the core for given flying speed. For a radiator mounted in an unobstructed position, the difficulties are inappreciable, the estimation process is replaceable by actual measurement and the results are obtainable with satisfactory accuracy. For a nose mounting, or other obstructed position, too many factors enter into the determination of the airflow to make generalizations possible. Consequently, without any intervening step, the authors are unable to include in the paper material of direct application, for the nose radiator, a mounting which is today probably the most common in American practice. The designer who is interested in such a mounting must first secure a measurement or estimate of the airflow to be expected in the core of his radiator, taking into account the size and shape of fuselage, engine, propeller and all the objects which will determine this airflow; then, with such data in hand, he can apply all the results of this paper.

Radiator Performance in Terms of Flying Speed

The paper is carried one step beyond expressing radiator performance in terms of airflow through the core, and states the results of the measurement in terms of flying speed for a mounting in an unobstructed position. Comparative performance is stated in terms of figure of merit, which is the ratio of the power dissipated as heat to the power required to sustain the weight of the radiator and overcome its head-resistance in pushing it through the air. The relative figures of merit of two cores in an unobstructed position do not, of course, furnish an index of value in an obstructed position. The comparative behavior of various classes of core are discussed in some detail for the unobstructed position and it is shown that for this mounting and high speed of flight, the flat-plate-core construction has a figure of merit sufficiently above other types to deserve attention. Its chief disadvantage is inherent mechanical weakness, a feature of extreme importance in selecting a design for use, and the data presented should afford the designer definite information regarding the sacrifice in figure of merit which must be balanced against increased sturdiness, when choosing between types of core. For flying speeds of 60 to 200 m.p.h., it seems certain that an unobstructed radiator plus a streamlined nose to the fuselage offers a figure of merit so much above that of a nose radiator installation as to justify considerable effort toward overcoming the structural difficulties attendant upon such a mounting.

The measurements made on a very wide range of variety of cores indicate that vanes, holes in the air-tube walls, and all devices intended to increase turbulence in the air-tubes are detrimental to radiators in an unobstructed position, lowering the figure of merit for a given flying speed. The effect is to decrease the airflow more than is compensated for by the increased heat-dissipating power at a stated rate of airflow. On the other hand, in obstructed positions, where the airflow is determined more by the radiator surroundings than by its own core construction, the cores with turbulence devices may be advantageous. For regularly shaped cellular tubes, with straight walls parallel to the wind and with no vanes or holes, an empirical formula was developed which was found to express airflow through the core in terms of flying speed, with a surprising degree of accuracy:

$$m = a\left[1 - (10)^{-44r/x}\right]$$

where r is hydraulic radius of an air-tube, the quotient of cross-section divided by perimeter, and x is depth of the core or the length of an air tube, both these dimensions being measured in the same unit of length; a, being the free area of the core, is the ratio of the total cross-sectional area of the air-tubes in a given frontal area to that frontal area; m is the airflow constant, the fractional part of the airflow approaching the core which passes through it; hence, unity minus the fractional part deflected around the core. In a windstream of 5 lb. per sec. per unit area, a core of unit frontal area which transmitted 3 lb. of air per sec. and deflected the other 2 lb. around it, would have an airflow constant of 0.60. The presence of headers or water-boxes would modify the direct application of the formula to a radiator, since the formula is for a core alone, but with the exercise of suitable judgment in making an allowance for water-boxes and connection piping it should be possible, from the geometrical characteristics of a simple core, to compute with a satisfactory degree of accuracy the airflow which would correspond to any stated flying speed with the core in an unobstructed position.

FARM TRACTOR PROSPECTS

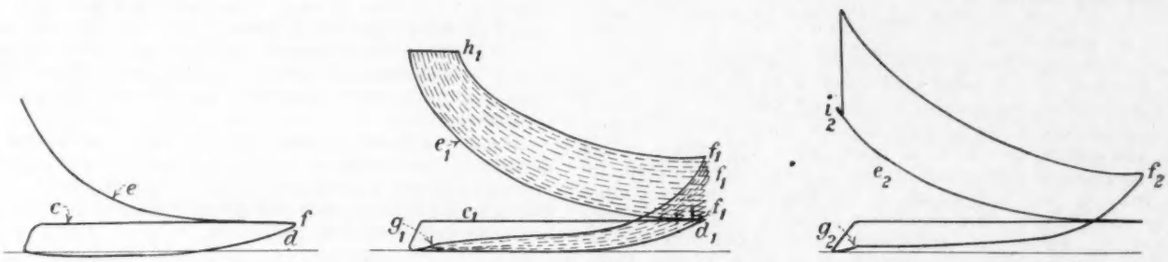
WE learn from the census that there are in the United States 2,673,345 farms containing 100 acres or more. One may concede for the sake of argument that tractors cannot be used economically on farms of smaller size, although there has been considerable testimony given by farmers themselves showing that tractors have been and are being used to good advantage on farms having an area of less than 100 acres.

What percentage of these farms has been supplied with tractors? The census bureau tells us that there were 246,139 tractors on farms at the end of 1919. The farm equipment production and sales statistics of the Department of Agriculture are to the effect that 162,988 tractors were sold to dealers in 1920. Not all of these were sold to farmers in that year, but many of them have been sold this year. The census figures plus the 1920 sales figures give a total of 409,127 tractors that have passed through the wholesale trade. With these figures it is not unreasonable to say that approximately 400,000 tractors are in use on the farms of the United States at present. There are still 2,000,000 farms, the owners or operators of which are more or less definite prospects for the sale of tractors. The time is coming when at least 2,500,000 American farmers will have bought tractors, and thereafter they will replace worn-out machines as rapidly as necessary in order that the tractors may always be a part of their regular equipment.—*Farm Implement News.*

SIDE GUIDE AND GRIPPER

Correction for Summer Meeting Discussion

IN connection with the remarks of Elmer A. Sperry in the discussion of the paper by Messrs. Mead and Pierce, which was printed in the October issue of THE JOURNAL, some unfortunate errors occurred in reproducing the indicator-cards that were supplied. In preparing these illustrations for publication the cards were sketched from a series of photographic reproductions of the original indicator-cards and errors occurred in these sketches that make the illustrations entirely at variance with the statements made in the text. The illustrations of these cards have been corrected and are reproduced herewith with the following word of explanation from Mr. Sperry.



THREE INDICATOR CARDS OBTAINED FROM A 10 TO 1 COMPOUND AVIATION ENGINE USING AUTOIGNITION AND HEAVY FUEL-OIL

From Left to Right These Are a Cyclic Card without Fuel, a Card Showing the Range of Control from 10 Per Cent Overload to Idling by Regulating the Amount of Fuel Injected and a Card Showing a Straight Detonation

In the illustrations, the cyclic card at the left, after the engine is hot, rises and falls on practically a single line e.

The card in the center illustrates the method of engine control, in contrast with the usual throttling, by varying the fuel added after the compression of the air. Lines c_1 and e_1 will at once be recognized, but in this card various amounts of fuel are added which burn on the slow Diesel cycle, and as more fuel is added, the card becomes thicker. The outer line from h_1 to f_1 indicates 10 per cent overload and from this down to idling, which is represented by the line nearest e_1. The parallel lines terminating in the various points of transfer f_1 f_1 indicate intermediate powers.

The card at the right is given to illustrate the peculiar integrity of the detonation, which has been supposed to originate from introducing the fuel with considerable "lead." Instead of this, here is an instance where the compression e_2 has actually started back from its highest point, as it does in the card at the extreme left, before any fuel is introduced, whereupon the fuel introduced at the point i_2 with about a 12 deg. "lag" instantly detonates, as indicated by the vertical line, and the same cycle of operation is carried out through the point of transfer f_2 into the low-pressure cylinder to the point of final exhaust-valve opening g_2. The contrast between this card and the one in the center is marked by the expansion line proper starting much higher and farther to the left, representing an almost true Carnot cycle, piling the heat up at the beginning of the card and as far away from the exhaust-valve as possible.

EUROPEAN SCREW-THREAD PRACTICE

IT seems that the American form of screw-thread is practically unused in Continental Europe. From rough data gathered it appears that the use of the Whitworth thread varies from 50 per cent in France to 90 per cent in Germany. Hence, all of the metric countries are keenly interested in the screw-thread situation, particularly Austria, Germany, Holland, Sweden and Switzerland, which are, it is reported by Secretary Agnew of the American Engineering Standards Committee, anxious to agree on tolerances for the Whitworth form of thread. They take the view that they should follow the Anglo-Saxon countries in this work but are anxious that if the Americans and the British are to reach any agreement this should be done as soon as possible, for they consider the question a pressing one.

It is understood that at least the following have already adopted, or are practically certain to adopt three systems of screw threads as their standards: Austria, France, Germany, Holland, Italy, Sweden and Switzerland. The systems referred to are the Systeme Internationale, the Metric Fine Thread and the Whitworth. These are shown in Swiss Standards Nos. 12,005, 12,006 and 12,007. The Germans have definitely decided to abandon several less used metric systems, having not over three in final use. They are much interested in the number of threads per inch for the very large Whitworth screws. Their shipbuilding industry wants to continue the use of pitches coarser than 4 threads to the inch, on account of its use on British ships, but the other German industries want to limit the number of threads per inch to 4, as recommended in the report of the National Screw Thread Commission of the United States of America that was recently issued.

Germany, Holland, Sweden and Switzerland are definitely on the basis of the nut as the fundamental, according to Mr. Agnew. The Swiss have done extensive work on the subject of screw-thread tolerances, which has not been published. It deals exclusively with the Metric and the Whitworth threads.

The published Dutch standard on bolts has been withdrawn and is now being revised. The British have organized an Association of Bright Nut and Bolt Manufacturers and this has greatly stimulated their work on the general question of screw threads and on the details of nuts and bolts. The British Association stated that the Society of Automotive Engineers' thread is being used in England and that they are undertaking to determine the extent of its use.

SIDE GUIDE AND GRIPPER

THE GENERAL FARM TRACTOR

I PROPOSE to discuss the tractors for the general farmer raising the crops to which are devoted the greatest acreages. These will range from 8-16 to 16-32-hp. machines.

The farmer is interested particularly in the design of tractor that will enable him to do satisfactorily and economically as large a part as possible of the work he is now doing with work animals and portable engines.

Cultivating

The cultivation of the crops requires a number of special features in a tractor, such as ample clearance, light ground pressure, a gage that will enable the machine to get through the rows without injuring the crop and as short a turning radius as practicable.

The crops requiring plowing but no cultivation occupy less than one-half of the total area devoted to all crops. Inasmuch as by far the greater number of farms of the South are very largely if not entirely devoted to the raising of both corn and cotton, and both of these crops are raised as far north as climatic conditions permit, it seems safe to estimate that fully 75 per cent of all of the farmers in the United States raise some corn or cotton or other crops requiring cultivation. From the standpoint of the total acreage devoted to crops requiring cultivation, in view of the large number of farmers raising such crops and bearing in mind that the peak-load in hours of horse-labor on farms raising such crops comes during the cultivating season for those crops, it is most decidedly worthwhile to consider a tractor that can be used for cultivating such crops as well as do the other work now being done by work animals and portable engines.

The roots of a row of corn are almost at the surface at the stalk and have their greatest covering of earth midway between the rows. The same thing applies to cotton and other row crops. Single-row machines, that is, tractors able to pass between two rows and cultivate one row, or two half-rows as it is frequently put by the farmer, would necessarily have their wheels travel near the stalks. This would probably result in cutting many of the roots, thereby decreasing the nutriment furnished the stalks by the roots and thus reducing the yield. The soil is usually in a more or less plastic condition. The wheels passing over it will compact it, more or less, not only directly under the wheels but, because of the plastic condition of the soil, underneath the stalks where the effect cannot be overcome by the cultivating implements following the wheels.

A number of machines have been placed on the market which straddled two rows and cultivated three rows at one passage of the machine. These tractors, as a rule, were stable, and their wheels traveled midway between the rows. The wheels were large, or the machines were equipped with crawlers. Nearly all of the machines were large, requiring considerable space in which to turn around. This meant wider headlands or turn-rows, and an increase in unproductive land, or, if the rows were not widened, damaged crops in adjacent cuts. These machines were largely if not entirely of the three-wheeled type which meant less accurate steering. Covering two rows of various widths, it was necessary to make the outer wheels adjustable laterally. This reduced the rigidity of the machine and unquestionably increased the cost of maintenance. Furthermore, the work of changing the wheels was more or less arduous. However, by far the most objectionable feature was that the operator had to cultivate three rows at one passage of the machine. This is more work than one operator can attend to properly.

Tractors straddling one row and cultivating two rows at one passage of the machine are on the market. Their wheels are large and travel midway between the rows. They are stable. They are fairly light in weight and therefore do not compact the soil to a serious degree. Any compacting that may be done can readily be overcome by the cultivating implements following the wheels. Straddling but one row, the wheels do not have to be made adjustable laterally, for a gage can be arrived at that will be but a few inches from the center of the rows or middles in any of the width rows these crops are normally grown. Therefore the frame can be made rigid, as far as the gage is concerned. These tractors are about half as wide as the three-row type and usually much shorter. The tractors of this type are practically all of the two-wheeled type. They require the addition of a two-wheeled implement or carrier to make them complete and operative. This really makes them four-wheeled tractors and leads to considerable duplication, for each implement designed for this type of tractor must have two wheels. Because of the necessarily compact form of these tractors they are, I believe in every instance, provided with but one speed forward and one reverse. This requires the operator to consume as much time in doing light work as in doing heavy work. Having but one speed, should the tractor become stalled at that speed, it is necessary to call for assistance to get out.

It seems safe to conclude that the tractor for the general farmer will be designed to straddle one row while cultivating two rows at one passage of the machine; and that, while the two-wheeled type is now popular, a four-wheeled tractor will be found even more desirable.

Gage and Clearance

The gage of the tractor would naturally be the average of the minimum and the maximum distances between the rows, since the wheels are not to be made adjustable laterally. Corn and cotton are grown normally in rows 3 to 4 ft. apart; therefore the average distance between rows is 42 in. The implement manufacturers have adopted a gage of 44 in. for implements to cultivate corn and cotton crops, which gives ample clearance laterally.

For ground clearance we can again turn to the implement manufacturers and benefit by their experience. They have determined that a center clearance of 32 in. is necessary for implements used in cultivating and laying by these crops at a time experience has indicated as proper for maximum yields. In lieu of other data we can adopt this as a minimum clearance for tractors for this purpose.

One or Two Men Per Tractor While Cultivating

Tractors have no eyes; they must be guided constantly. We propose to increase the speed very materially. We expect a single operator to do satisfactorily work that in the earliest stages of the crop was frequently unsatisfactorily done at slow speed and with the assistance of the eyes of the work animals. I am sure that it would prove disastrous when the crop is young and tender. After the crop grows hardier it may perhaps be possible to devise some sort of fenders to assist the operator, but I question the wisdom of using but one man per machine for this work. The constant jerking up of his head to see how to steer and down again to look at the implements to be assured that they are doing their work properly and not injuring the crop, would soon tire the operator so that he would have to quit or do slovenly work; adding expense to the cost of cultivating the crop which to me appears greater than that of another man to give undivided attention to the cultivating implements.

Harvesting the Crop

Harvesting is one of the largest items entering into the cost of producing crops. Every acre cultivated must be harvested, and the acreage devoted to hay is frequently harvested several times per year. The cotton and tobacco crops, a part of the corn crop and perhaps some of the other crops are still harvested by hand. But by far the majority of the harvesting is done with some form of harvesting machinery, such as binders.

Practically all forms of harvesting machinery are designed with a cutter-bar, or some other harvesting device, extending to one side of the machine. The work animals are hitched ahead of the machine. Thus the power is ahead and

the resistance to one side. This causes a slueing tendency, and frequently the machines do slue, especially with heavy crops. When tractors are used to replace the work animals on these machines the slueing tendency is undoubtedly aggravated.

With the cutter-bar to one side and to the rear of the operator it is impossible for him to keep his eyes constantly on it, whether the motive power is work animals or a tractor. As a result the cutter-bar is frequently run into an obstruction. When this occurs with work animals they feel the tug and stop, and as a rule no damage is done. Tractors, however, have no feelings, and, the resistance of the cutter-bar being insufficient to overcome the power of the tractor, it is broken. This puts the implement out of commission until it can be repaired or replaced, a serious interruption when harvesting.

The pushing of implements is not impracticable with a tractor. By properly attaching them to the tractor the weight of the latter can be used to hold them steady and against the work. Naturally, desiring to push an implement, the first impulse is to fasten it to the front of the tractor. This has been done by several designers of harvesting implements which were brought out in the past year or two. From what I can learn these implements or attachments did very efficient work. To fasten them to the front of the tractor apparently a rather elaborate system of braces and connections was found necessary. The operator of the tractor, seated behind the steering-wheel to the extreme rear end of the tractor, was unable to see what the harvesting implement was doing or where it was going. Therefore an additional man was placed, in one case, on the radiator of the tractor, to look after the harvesting implement and apparently to direct the tractor operator as to the course he was to steer.

If it is conceded that it is best to apply the power to the harvesting implement directly behind it and to push it rather than pull it, and also that it is not desirable to attach the implement in front of the tractor, we have but one other solution, to attach the harvesting implements to the rear of the tractor and run the tractor backward, or in reverse, thus pushing the implements. This arrangement has several decided advantages. The tractor is designed and built so that attachments can be fastened at its rear end.

To push implements efficiently and with ease by running the tractor in reverse, and to pull them by running the tractor forward, the steering-wheel will have to be arranged so that the operator can sit in front of it facing backward, relative to the tractor, when pushing implements, as well as sit behind the steering-wheel facing forward, relative to the tractor, when pulling implements. This arrangement will enable the operator to face in the direction the tractor is moving and steer it in perfect comfort. By arranging the steering-wheel in this manner and leaving it at the rear of the tractor the operator will have the implements directly before his eyes constantly, while giving his attention to steering the machine, because they will be in the line of travel of the tractor. This puts no extra strain on the operator and therefore the additional man needed when harvesting implements are fastened to the front of the tractor can be dispensed with. The saving thus effected each season will probably pay several times over any additional cost in building the tractor so that it can push implements when going in reverse and pull them when going forward.

Universal Central Control and Speeds

Granting that the tractor is to run in reverse when harvesting and forward when plowing or cultivating, and that it will have more than one speed in reverse and probably as many in one direction as in the other, it is decidedly desirable to equip it with a universal central control, by which I mean an accessory, that will enable the operator to run the tractor, as readily when pushing implements as when pulling them.

The tractor should always be equipped with an extremely slow speed of great power, much slower than any normal working speed. This speed is to be used on heavy grades or in bad ground and might be fixed at approximately 1 m.p.h.

The tractor should be provided with a "plowing speed," a speed at which the drawbar-pull is sufficient to overcome the resistance readily, under the severest normal conditions, of the number of plows it is designed for. This speed has been fixed, for the present at least, by the Society of Automotive Engineers, at 2 1/3 m.p.h. for tractors having a drawbar horsepower of 15 or less. This would cover the machines here under discussion. How long this rate, in fact any rate, will remain standard will depend on the degree of success met with in the many tests now being made by the advocates of higher-speed plowing.

The power required to overcome the resistance of the ordinary cultivating implements is less than that required for plows when breaking land in the same soil. Many advocates of two or more machines per farmer point to this fact as being in favor of their position, because an engine operates more efficiently and economically when working under its normal load. Since the drawbar-pull for cultivating requirements is less than for plowing, why not increase the speed when cultivating until it multiplied by the cultivating drawbar-pull equals the plowing speed multiplied by the plowing drawbar-pull, when the power requirements would be equal? This would not only permit the engine to be operated under the most efficient and economical conditions but enable the tractor to cover much more of an acreage in a given time, thus reducing the cost of the work. It may be argued that a speed for cultivating to use the full power of the engine would be too great to permit the operator to cultivate properly. That is true when but one man is used for this work. However, I have already shown that it is highly improbable that one man can cultivate properly with a tractor at the ordinary speeds. With two men, however, one giving his entire attention to steering the tractor while the other gives his entire attention to the cultivating implements and the proper cultivation of the crops, this objection would probably be entirely overcome. In fact it is quite possible that better work would be done under those conditions, that is, at higher speeds with two men, because the work would be coming fast enough to demand their entire attention all of the time, thus giving them no opportunity to get slovenly about their work. It may be assumed that the position here taken is inconsistent with the one advocating two men while cultivating. I do not think so, for, in advocating two men while cultivating, the matter objected to was the incessant changing of the work from that of steersman to that of cultivator and back.

So far as I know no data have been published giving the drawbar-pull for plows when breaking land and for cultivating implements when cultivating that same land. I suggest an increase of about 50 per cent over the plowing speed, or say, for the present fixing the cultivating speed at about 3¼ m.p.h.

Summing up, we may fix, from the present knowledge of tractor speeds, desirable speeds for a tractor for the general farmer, about as follows:

First, or "trouble speed," 1 m.p.h.
Second, or "plowing speed," 2.33 m.p.h.
Third, or "cultivating speed," 3.75 m.p.h.
Fourth, or "road speed," 5 m.p.h.

The position may be taken that so many speeds in reverse are not necessary. It will be shown under "Power for Attachments" that there will be a decided advantage in having a number of speeds for harvesting implements, and, in accordance with the position here taken, this work is to be done with the tractor traveling in reverse.

Belt Work

Tractors should, of course, be equipped for belt work. Most, if not all, of them are equipped with proper gearing, a clutch and a belt pulley. The Society of Automotive Engineers has adopted certain speeds as standard so that not only tractor designers know what speed to give the belt pulley of the tractor, but designers of farm equipment requiring power can be assured of having their equipment run at the proper speed for best results by giving that equipment a pulley of the right diameter. There is one point, however, that it

seems might receive some attention. The pulley, to be effective and readily lined up with the pulley of the equipment to be driven, should extend beyond the frame of the tractor. This construction, while of advantage in lining up the belt pulleys, is not desirable at other times. The pulley, extending beyond the frame, is liable to catch on obstructions or gate-posts, which may result seriously, even to bending the pulley shaft. The season for using the pulley is a limited one and it usually comes all at one time. The rest of the time the pulley is an incumbrance. Why not make the pulley readily detachable and as readily reattachable in only the correct way?

Flexibility

By "flexibility" is meant a design of frame that will enable two of the wheels to oscillate about a common horizontal longitudinal axis in such a way that all four wheels can remain on the ground when moving over rough terrain or drainage ditches, without in any way warping the frame of the tractor. This is necessary to assure ease of operation and long life, and to make the tractor as light in weight as possible, for, if sufficient flexibility is not provided the frame of the tractor must be made sufficiently strong to overcome the warping tendency when the tractor moves over rough ground or farm ditches, and therefore heavier, or the engine, transmission, etc., will be thrown out of alignment, which will reduce the life of the tractor.

Wheels

Tractors should be equipped with as large wheels as is practicable. Small wheels make it difficult to pass over rough ground and drainage ditches without danger of stalling the tractor; tractors are frequently stalled because of small wheels. Furthermore, considerably more power is consumed in propelling a tractor with small than with large wheels.

Springs

Spring mountings should be used to as great an extent as possible without tending to make the tractor more complicated and therefore increasing the cost of maintenance. Simplicity of design with springs tends to reduce the wear-and-tear on a tractor and increases the comfort of the operator very considerably.

Weight

The tractor should be built as light in weight as is consistent with proper strength and traction. Only sufficient weight is necessary to cause the lugs to penetrate the soil to their full depth while the tractor is at work, thus enabling it to develop its full drawbar power. Sufficient weight, in the case of tractors having their drive-wheels in the rear, should be placed over the front wheels to keep them from leaving the ground or rearing up when the tractor is exerting its maximum drawbar power or when going up any incline that may reasonably be expected in the ordinary performance of its duties. While much has been done in reducing the weight of the better designed tractors it seems reasonable to expect that still more can be accomplished by the use of steel and other alloys in the frame and in other places without interfering with the traction or the power of the machine, and also not reducing the weight on the front wheels unduly.

Special Attachments

Farmers' Bulletins Nos. 719 and 963 both contain a statement from which the following extract is taken:

> It is obviously impossible to obtain maximum results with a tractor when it is used with implements designed primarily for use with horses, and the objection of many tractor owners that the tractor cannot be used with profit for certain types of field work will probably cease to hold good with the development of special machinery for use with the tractor

This merely voices the sentiment of practically every one who is giving much thought to the ultimate design of the tractor. The tractor must be a complete machine and ultimately will be designed as a complete machine, attachments and all.

Power-Lift

There seems to be no reason why a power-lift cannot be included in the design of the complete machine, so that the attachments can be raised and lowered by the power of the engine on the tractor. This accessory could be very simple and inexpensive. It would increase the cost of the complete machine very little. The farmer would gladly pay for the increased convenience.

Power for Attachments

There is no reason why attachments requiring power for their proper manipulation cannot derive it direct from the engine on the tractor instead of having the power passed from the engine, through the tractor drive-wheels, then through the bull wheel of the attachment or implement, as is now done with animal-drawn implements, such as mowers and binders. The engine supplies the power in any event. Why not by the most direct and least power-consuming way? One tractor building company has recently recognized the desirability of this feature by bringing out a model that has a connection to supply power to one of its implements direct from the engine. This accessory could be made simply and inexpensively. It would not be necessary to equip it with a variable-speed transmission. Extra sets of gears or sprockets could be provided, should more than one speed be found necessary.

In the case of harvesting implements, such as mowers and binders, the supplying of power from the engine direct to the cutter-bar would be of distinct advantage. The cutter-bar could be operated at such a constant speed as experience has indicated produces the best results. Then the tractor could be run at a speed that would, as nearly as possible, feed the crop to the cutter-bar at its full capacity. The running of the cutter-bar at a constant speed and the tractor at a variable speed while harvesting is made possible through equipping the tractor with more than one speed in reverse.

Fool-Proofness

Tractors are not infrequently placed in the hands of unskilled and even ignorant labor. Therefore it is positively essential to make them as fool-proof as possible. All gearing should be housed to prevent accident, if this has not already been done to permit efficient lubrication and to reduce the wear and the power required to move the tractor. The manipulation of the tractor should be made as simple and as easy as possible. Attention to all of these points will increase the efficiency of the operator and enable him to accomplish more work in a given time, reducing the cost.

Summary

Therefore the query, "What form will the tractor ultimately take?" may be very largely answered by stating that it will be the form that will embody the features that will enable the general farmer to do in a more economical and efficient manner all of the work on his farm that he is now doing with work animals and portable engines.—From a paper by W. C. Zelle presented to the American Society of Agricultural Engineers.

Artificial versus Natural Means of Drying Paint and Varnish

By R. E. LIPPERT

CLEVELAND SECTION PAPER *Illustrated with* PHOTOGRAPHS AND DRAWINGS

THE author describes a process for drying coats of paint and varnish more rapidly than is possible with natural means, by adding heat and moisture simultaneously to the air surrounding the siccative coatings, through the employment of mechanical devices. The use of a fan and conditioning equipment to produce air circulation allows the process to be adapted readily to modern factory-schedules.

Atmospheric conditions suitable for drying are discussed at some length as being a composite of sensible temperatures and relative degrees of humidity, and several humidifying devices are described and illustrated. Color control of paint by this means of drying is mentioned, examples being given, and numerous photographs showing installations of artificial drying equipment in use at various automobile plants are presented.

THE paint-shop seems to be the one department in the automobile business that did not receive due consideration when the industry was established on a quantity-production basis, and as a general rule this department does not make as favorable a showing as the other departments of the plant. The obvious solution is to adopt better and more efficient methods so as to multiply the output per man and per unit of equipment. The process I will describe provides a means for drying coats of paint and varnish more rapidly, thereby putting the paint-shop on a quantity-production schedule without sacrificing the quality of the work produced. This process eliminates the uncertain element of time by enabling the manufacturer to establish a fixed production-schedule that will function uniformly in spite of constantly varying weather conditions. In its simplest form the process consists of simultaneously adding heat and moisture to the air surrounding the siccative coatings of paint or varnish. The use of a fan and conditioning equipment to produce air circulation allows the process to be adapted more readily to modern factory schedules, but the underlying principle is the same today as it was when the process was discovered by Dr. William H. Grosvenor 15 years ago.

Paint and varnish will air-dry successfully, because air always contains some moisture and some degree of heat, but successful air-drying depends entirely upon storage facilities, weather conditions and other factors. The drying time varies with atmospheric conditions and, since it does vary, there must be at least one definite condition under which a certain grade of paint or varnish will dry most rapidly and successfully. When such a condition is once established, it should be maintained uniformly throughout the entire drying period, and it should be possible to duplicate the condition and eliminate the element of chance whenever and wherever desired. Nature herself may, somewhere and at some particular time, furnish weather conditions somewhat approximating the degree of heat and moisture required to dry paint and varnish properly, but the most favorable and most unusual of such natural weather conditions are variable, of short duration and of unforeseen termination. Moreover, so many different grades of paint and varnish exist, containing such varying proportions of oxidizable oils, that it is manifestly impossible to establish one standard ideal atmospheric condition for drying each of them, and it is absurd to expect nature to comply with so many different sets of specifications. Thus the necessity arises for supplementing natural atmospheric conditions with some artificial means of (*a*) establishing an ideal drying atmosphere at will, (*b*) maintaining such an atmosphere uniformly for the drying period, and (*c*) being able to duplicate or vary this condition as desired.

Unfortunately, atmospheric conditions are measured not only in degrees of temperature, but also in percentages of relative humidity. The mere fact of maintaining a uniform temperature does not presuppose a uniform relative humidity, unless means are provided for adding moisture and controlling such additions by proper me-

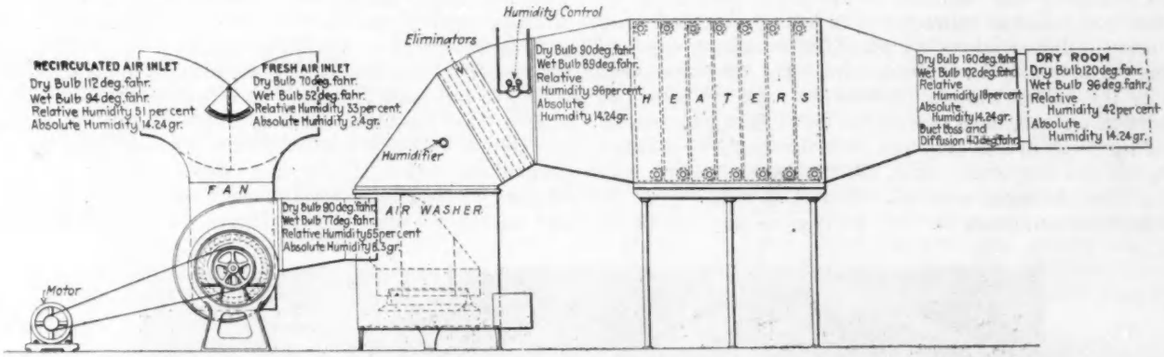

Humidity Control
Eliminators
RECIRCULATED AIR INLET
Dry Bulb 112 deg. fahr.
Wet Bulb 94 deg. fahr.
Relative Humidity 51 per cent
Absolute Humidity 14.24 gr.
FRESH AIR INLET
Dry Bulb 10 deg. fahr.
Wet Bulb 52 deg. fahr.
Relative Humidity 33 per cent.
Absolute Humidity 2.4 gr.
Dry Bulb 90 deg. fahr.
Wet Bulb 83 deg. fahr.
Relative Humidity 96 per cent.
Absolute Humidity 14.24 gr.
H E A T E R S
Dry Bulb 160 deg. fahr.
Wet Bulb 102 deg. fahr.
Relative Humidity 18 per cent.
Absolute Humidity 14.24 gr.
Duct loss and Diffusion 43 deg. fahr.
DRY ROOM
Dry Bulb 120 deg. fahr.
Wet Bulb 96 deg. fahr.
Relative Humidity 42 per cent
Absolute Humidity 14.24 gr.
Humidifier
FAN
Dry Bulb 90 deg. fahr.
Wet Bulb 77 deg. fahr.
Relative Humidity 55 per cent
Absolute Humidity 8.3 gr.
AIR WASHER
Motor

FIG. 1—DIAGRAM SHOWING THE OPERATION OF AN INDIRECT HEATING SYSTEM EQUIPMENT WITH A COMBINATION AIR-WASHER AND HUMIDIFIER

[1]A.S.A.E.—Sales engineer, Drying System, Inc., Chicago.

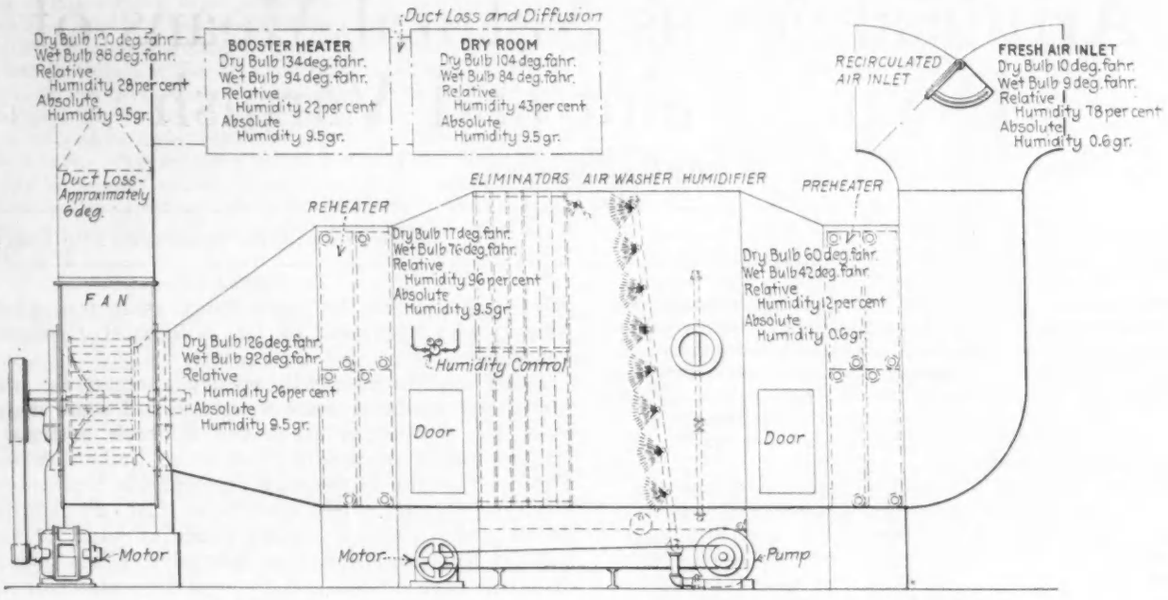


FIG. 2—A TYPICAL VARNISH DRYING INSTALLATION WITH A SPRAY-WASHER

chanical devices. The moisture content of the air is fully as important a factor in the drying of siccative coatings as the temperature of the air itself. When the idea of artificially drying paint and varnish was first conceived, it was the general belief that moisture would retard rather than hasten the drying process. Several years of earnest endeavor was required to prove the contrary. In fact, the true value of humidity was not appreciated even after several installations of humidity-equipped drying-systems were made and tried. Its only then-apparent value to the trade was to prevent surface or so-called case-hardening but, as a matter of fact, the main reason for adding moisture is that the moisture acts as a catalytic agent and cooperates with the increased heat in performing the chemical reaction of oxidization. This is the important function in the drying of any siccative coating, and it is entirely foreign to the purely physical evaporation of volatile solvents.

Having established the fact that certain definite atmospheric conditions are not only desirable but necessary, and being convinced that nature can provide such conditions only on rare occasions, it becomes necessary to furnish the proper mechanical means for creating artificially suitable drying weather to produce a standard finish of good appearance and greater durability. If we concede the value of humidity, the simple installation of steam coils will not suffice, even if they are thermostatically controlled. Let us assume, for example, that a certain grade of varnish will dry perfectly in a dryroom having a temperature of 120 deg. fahr. and that a relative humidity of 42 per cent means that there must be 14.3 gr. of moisture per cu. ft. of air. To duplicate such a condition in a

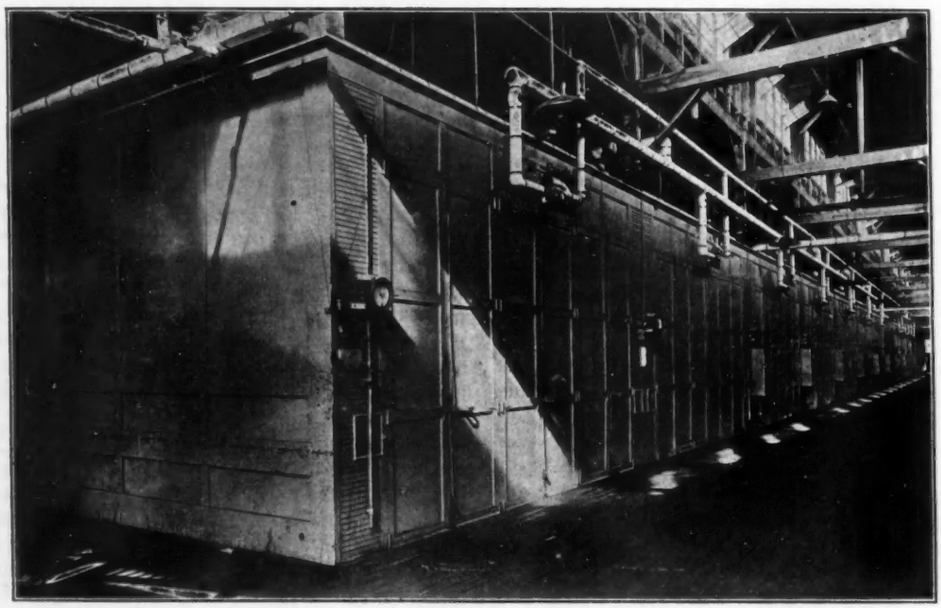


FIG. 3—A SERIES OF BODY DRYROOMS INSTALLED ABOUT EIGHT YEARS AGO THAT POSSESSES SUFFICIENT CAPACITY TO HANDLE 50 BODIES PER DAY ON A 12-COAT SCHEDULE

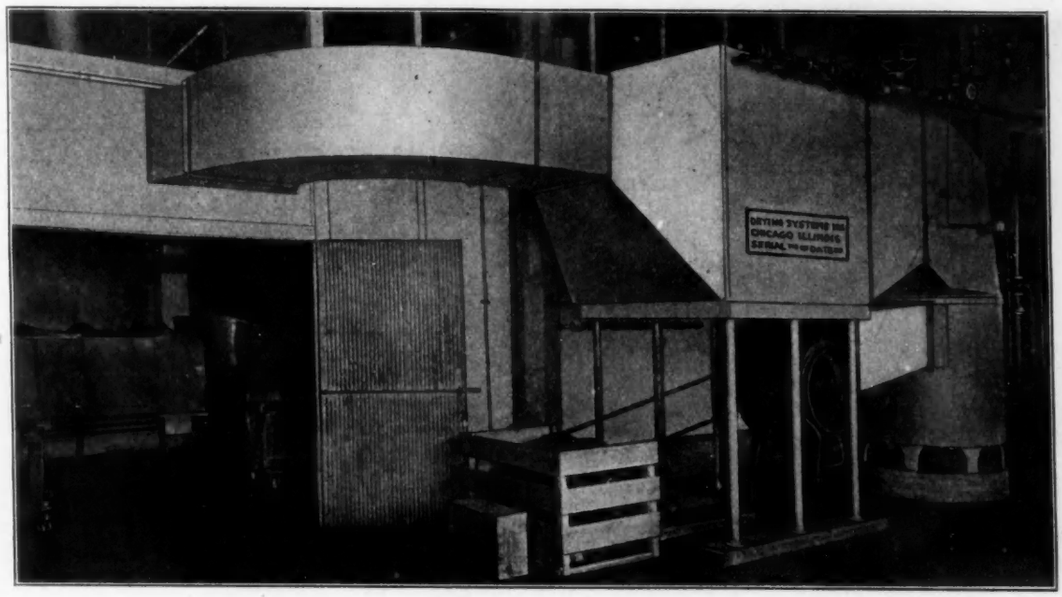


FIG. 4—A DRYROOM IN WHICH THE BODIES ARE RUN IN ON SMALL WHEELED TRUCKS

dryroom containing only steam-coils would necessitate an outside temperature of from 90 to 100 deg. fahr. with relative humidities ranging from 73 to 100 per cent. It is a matter of record, however, that in the vicinity of Cleveland the average moisture-content of the air ranges from about 1 gr. per cu. ft. in January to about 6 gr. per cu. ft. in July. But air at natural temperatures containing 1 gr. per cu. ft. when heated to 120 deg. fahr. will have only a relative humidity of about 3 per cent and even the maximum of 6 gr. per cu. ft. results in only a relative humidity of 18 per cent at that temperature, whereas 14.3 gr. is required to produce the desired results. Hence, some suitable means must be provided to make up the deficiency in the moisture content of the drying air if we propose to establish a uniform condition, and it merely becomes necessary to select the most suitable means.

HUMIDIFYING DEVICES

We have tried and discarded a great number of humidifying devices such as water-pans, water-screens and steam-jets. Our best results have been obtained by the use of an indirect heating system equipped with a combination air-washer and humidifier. In this way we have not only obtained accurately controlled conditions of temperature and humidity, but it has been possible to eliminate dust, dirt, insects and other foreign matter from the drying air. Fig. 1 gives a general idea of how and why this type of drying equipment operates and shows a typical section of such an equipment consisting of a motor-driven fan, an air-washer and humidifier, a series of steam-coils or radiators, temperature and humidity controlling devices and a duct system for air supply, circulation and ventilation. The ducts, which are not shown, are arranged in a suitable manner so that the conditioned air is uniformly distributed. From the standpoint of economy, it is customary to recirculate the air partially and hence two connections to the fan inlet are provided. To afford a concrete example of the action that takes place as the air passes through the machine, let us assume that it is desired to operate a dryroom at a temperature of 120 deg. fahr. and a relative humidity of 42 per cent on a day when the shop temperature is 70 deg. fahr. and the relative humidity 33 per cent. Since the duct loss and diffusion within the dryroom will necessarily cause some heat loss, which is assumed to be 40 deg. fahr., it will be necessary to raise the temperature of the air from 70 deg. to a final temperature sufficiently in excess of 120 deg. to compensate for this loss and to increase the moisture content from 2.4 gr. per cu. ft. or 33 per cent at 70 deg. fahr. to 14.3 gr. per cu. ft. or 42 per cent. at 120 deg. fahr.

It is desirable to recirculate part of the air; so, in this case it is assumed that 50 per cent is fresh air from the shop and 50 per cent is air recirculated from the dryroom. From past experience we have found that the recirculated air will return at a temperature of about 112 deg. fahr., with a 14.3 gr. per cu. ft. moisture-content, and a mixture of the two when delivered to the air-washer will have a temperature of approximately 90 deg. fahr. and an actual moisture-content of approximately 8.3 gr. per cu. ft. This mixture then enters the air-washer. The air and water come into intimate contact with each other and any drop in temperature sustained

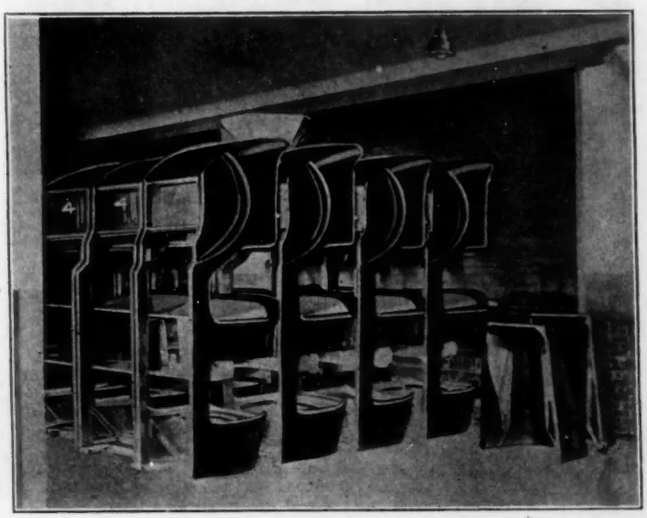


FIG. 5—INTERIOR VIEW OF A DRYROOM IN WHICH THE BODIES ARE UP-ENDED

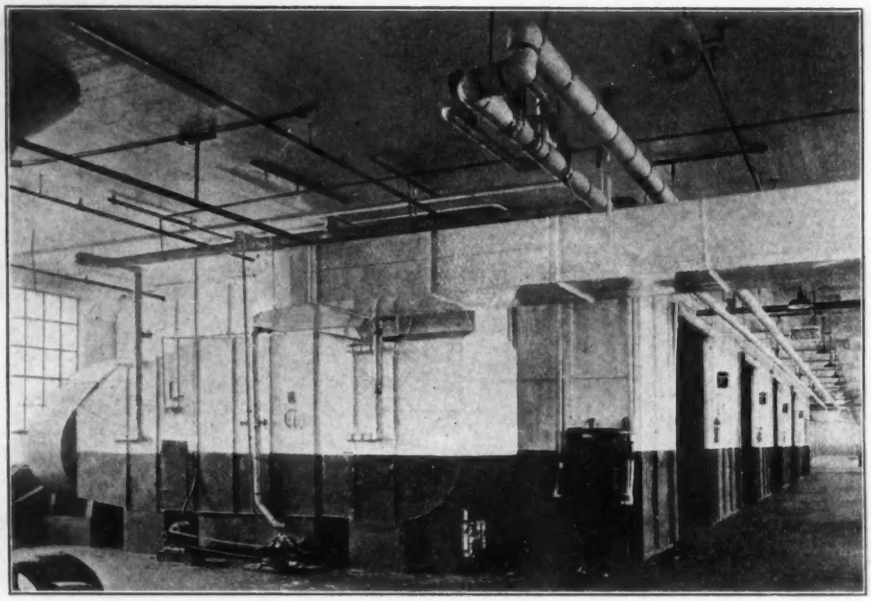


FIG. 6—A SERIES OF COLOR VARNISH DRYROOMS OPERATED BY AN EQUIPMENT HAVING A DAILY CAPACITY OF 150 BODIES

here is made up when the air passes through the steam humidifier, which also completes the saturation. The air after passing the washer has therefore reached a temperature of 90 deg. fahr. and carries the requisite 14.3 gr. of moisture per cu. ft. It shows a relative humidity at this stage of 98 per cent, or practically complete saturation, and the only operation that remains is to raise the temperature to 160 deg. fahr., which is the desired dryroom temperature of 120 deg. plus the assumed duct and diffusion loss of 40 deg. This can be done without any loss of absolute humidity. The heaters are either cast-iron radiators or pipe coils fed by one common manifold. The steam supply system is equipped with a diaphragm valve that is operated automatically by an expansion thermostat located in the dryroom. When the air has passed the heaters it will be virtually at 160 deg.

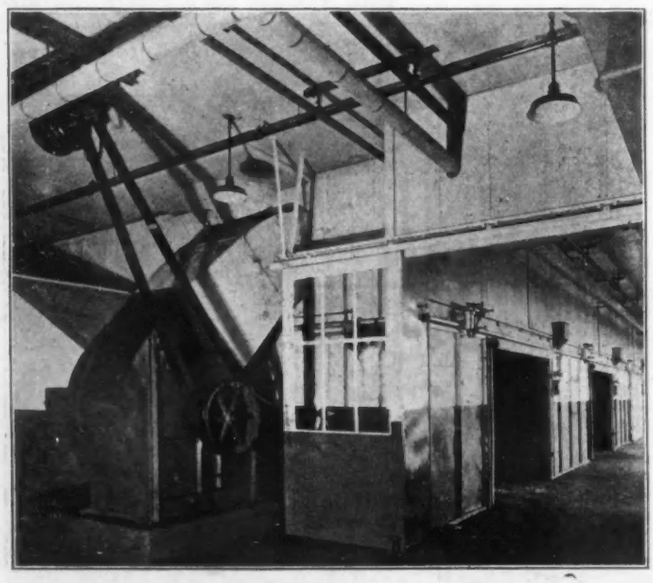


FIG. 7—DARK ROOMS FOR FINISHING VARNISH

In This Plant the Finishing Coat Is Applied during the Day and Dries at Night so That the Bodies Will Be Ready for Final Assembly in the Morning

fahr., with only 18 per cent of relative humidity at this point, but the absolute humidity still remains at 14.3 gr. per cu. ft. and the final condition obtained in the dryroom will be correct both as to temperature and humidity.

We have found the most successful method of controlling humidity to be the dew-point control. The principle of its operation is that the amount of moisture that air can carry at saturation is dependent on its temperature. For instance, having determined that a relative humidity of 42 per cent at a temperature of 120 deg. fahr. is desired, we know that an absolute humidity of 14.3 gr. of moisture per cu. ft. must be provided. Our humidity tables show that a moisture content of 14.3 gr. per cu. ft. represents saturation at a temperature of 90 deg. fahr.; the dew-point for this condition, therefore, is 90 deg. and by simply setting the humidity control for that temperature the desired result is obtained. Fig. 2 shows a typical varnish-drying installation with a spray washer which operates on the same general principle as the static type. We use this kind only when the capacity of a single unit exceeds 15,000 cu. ft. per min., because the first cost of a static washer is much lower than that of the small spray machines that require a motor-driven pump to force the water through the nozzles; otherwise the features are the same as for the static washer.

COLOR CONTROL

We have found that it is possible to establish an absolute color standard by this means of drying, even with the most delicate colors. The proper use of humidified air will eliminate the troubles resulting from off-color painting jobs, especially when using light blue, yellow, white or gray. Tests recently conducted with five different shades of blue demonstrated conclusively that the colors dried under proper humidity conditions could not be distinguished from those that were air-dried. Further, it was found that each one of the blue samples required a different relative humidity to produce the same likeness as was shown by its air-dried counterpart. For example, body No. 1 was dried with a relative humidity of 35 per cent at 130 deg. fahr. and showed a greenish overcast; but body No. 2 coated with the same varnish and dried with a relative humidity of 45 per cent could not be dis-

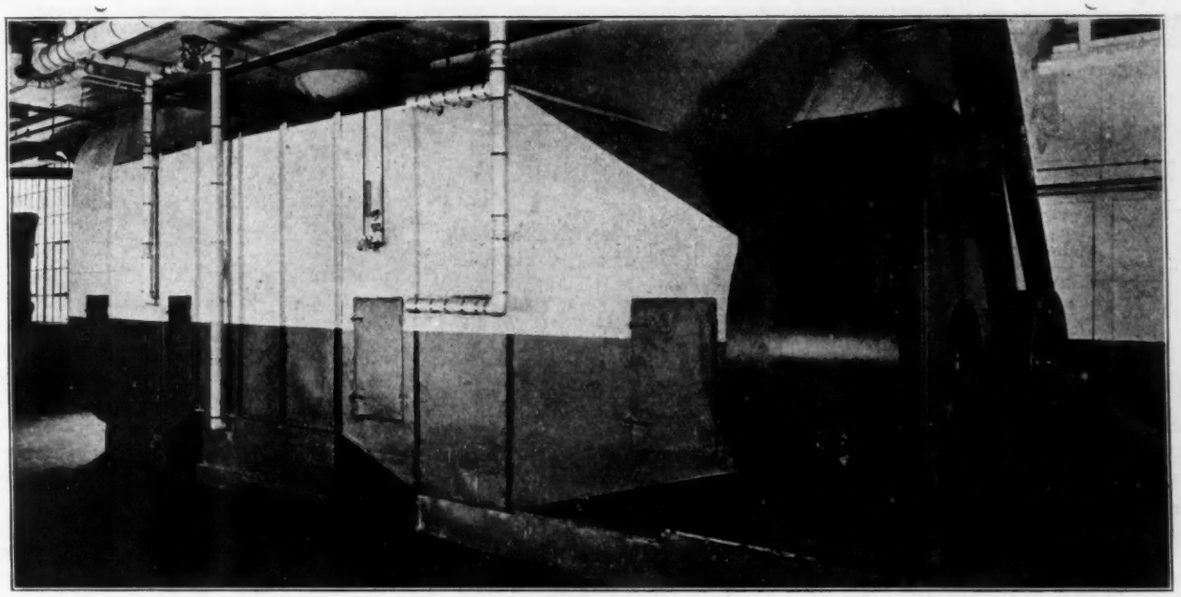


FIG. 8—CLOSE-UP VIEW OF THE EQUIPMENT OPERATING THE DRYROOMS SHOWN IN FIG. 7

tinguished from the air-dried sample. Bodies Nos. 3 and 4 coated with a different shade of blue and dried with a relative humidity of 35 and 45 per cent respectively were both failures; but were produced perfectly true to shade with a relative humidity of 55 per cent. A temperature of 130 deg. fahr. was used for all tests. We have worked out a table for practically all the known colors used in the industry. The only way to dry such colors successfully is to establish a schedule of temperatures and humidities that can be duplicated whenever required.

INSTALLATIONS OF ARTIFICIAL DRYING EQUIPMENT

Fig. 3 shows 10 body dryrooms that were installed in a Detroit motor-car plant about eight years ago. Seven of the rooms are 20 x 30 ft. and three of them are 20 x 45 ft. The total installation is sufficient to handle 50 bodies per day on a 12-coat schedule. The equipment recently installed at the assembly plant of a popular-priced car is arranged so that the bodies are up-ended on a conveyor that runs through the dryroom which measures 24 x 164 ft. With this equipment they are handling 300 touring-car bodies per day on a two-coat low-temperature enamel schedule. Fig. 4 shows an installation at a plant in Toledo where the bodies are not up-ended. Fig. 5 is an interior view of a dryroom where the bodies are up-ended. Fig. 6 shows a series of color varnish dryrooms operated by one equipment designed for 150 bodies per day; another equipment at the same plant is used for the block-off and striping work. Fig. 7 shows the dark rooms for finishing varnish, the finishing coat being applied during the day and dried overnight so that the bodies will be ready for final assembly in the morning. Fig. 8 shows a close-up view of the equipment that operates the dark room. This delivers 30,000 cu. ft. of air per min. With one machine of this kind it is possible to operate a series of rooms. By equipping each room with a set of booster heaters individual control is obtained and each room can be operated as an independent unit.

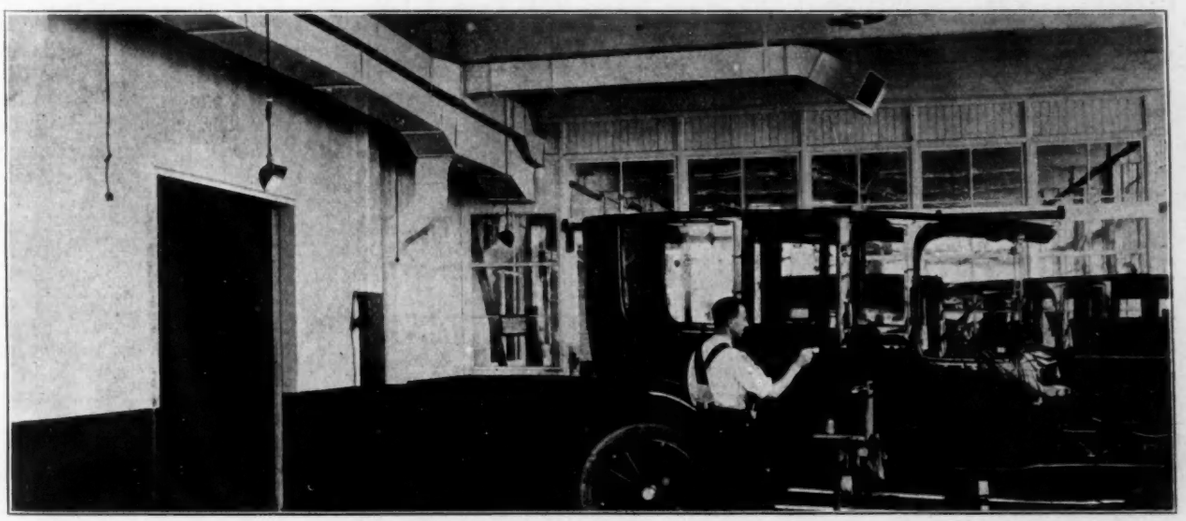


FIG. 9—A COMBINATION FINISHING AND DRYING ROOM

The Finishing Coat of Varnish Is Applied during the Daytime under the Most Favorable Temperature and Humidity Conditions and in the Evening the Automatic Controls on the Equipment Are Changed so That the Bodies Can Be Dried Overnight

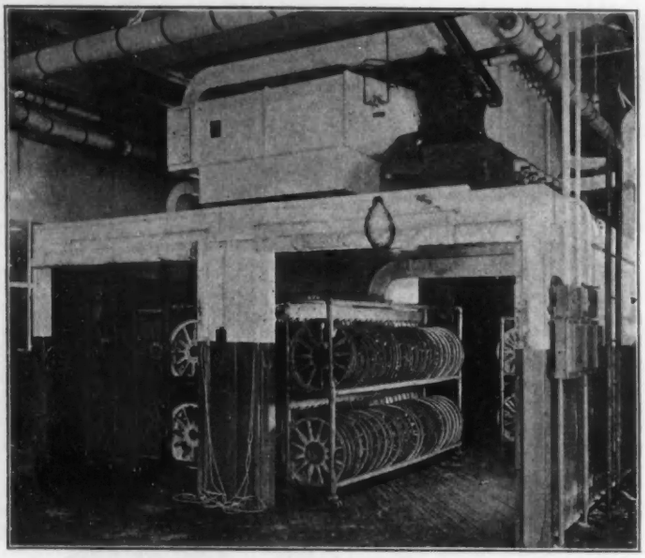


FIG. 10—A BATTERY OF WHEEL DRYING ROOMS

Fig. 9 shows the combination finishing and drying room at a plant in Buffalo. Throughout working hours this machine maintains the temperature and humidity best suited for applying the finishing varnish. In the evening the automatic controls are changed and the same equipment dries the bodies overnight at a temperature of 104 deg. fahr. and a relative humidity of 48 per cent. The bodies are mounted on their chassis, which appears to be a very satisfactory method for high priced cars produced in small quantities, but when running on a large-production schedule it would not pay because the space occupied by a completely mounted body is too great. One of the most important features of this type of installation is that it eliminates the dust and dirt and still provides fresh ventilated air in which the men can work. In summer an 8 or 10-deg. temperature-variation between the inside and the outside air is highly appreciated by the men who do the work. At a test recently conducted in a finishing room similarly equipped we were able to maintain an inside temperature of 86 deg. while the temperature outside registered 94 deg.

Fig. 10 shows a battery of wheel dryers recently installed at a Detroit factory. Little, if any, changes from earlier installations have been made in the method of handling the wheels. Fig. 11 is an interior view of the dryroom at a plant where the assembly line is combined with chassis-painting operations. A room of this size with a 45-min. drying period will handle about 125 jobs per day. Fig. 12 shows another chassis dryroom and the return-line for empty trucks. Fig. 13 illustrates a motor-truck installation that shows the adaptability of the system to other than passenger-car work and also indicates detail of the cable-type conveyor with which this dryroom is equipped.

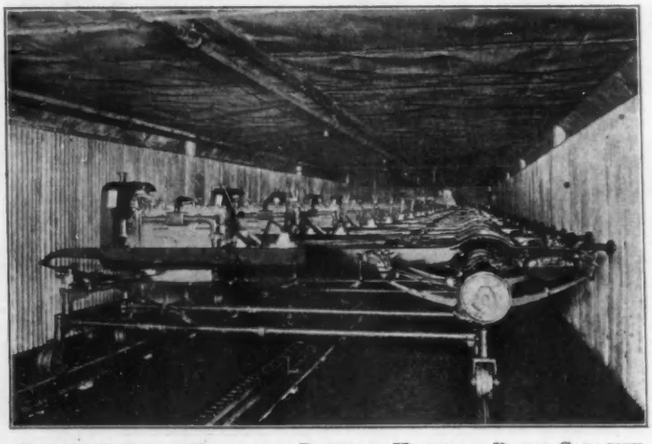


FIG. 11—INTERIOR VIEW OF A DRYROOM HAVING A DAILY CAPACITY OF APPROXIMATELY 125 BODIES BASED ON A 45-MIN. DRYING PERIOD
In This Plant the Assembly Line Is Combined with the Chassis Painting Operations

Some of the illustrations were taken seven or eight years ago and are offered as evidence that aside from some material improvement in the type of drying equipment used there has been no radical change in paint-shop production methods. While a reliable drying equipment will solve the underlying difficulties it seems that some actual changes in the production methods are necessary to put the paint-shop on the same efficient operating basis as the remainder of the plant. It is safe to assume that in no other department of the plant can such a large saving of money be effected by the installation of modern equipment. A preliminary investigation of this matter is now under way and I believe that a system has been devised whereby an automobile body can be completely finished and trimmed, using a standard 12-coat schedule, in four and one-half working days, at a saving of between $6 and $7 per body. To a plant producing 200 cars per day this represents an annual saving of $400,000 which, measured in banking-house terms, represents 6 per cent interest on over $6,000,000.

THE DISCUSSION

JOHN MCGEORGE:—From what has been said I gather that the term "drying action" amounts to nothing.

R. E. LIPPERT:—It is a drying action only in name. It is really a double action; first, the purely physical reaction exemplified by the evaporation of the volatile solvents; second, the chemical reaction effected by the oxidation of the oils. When linseed oil is oxidized, linoxid is produced.

MR. MCGEORGE:—Would you call that a baking?

MR. LIPPERT:—It is not a baking. If water is evaporated from a pan, its chemical composition is not changed; it is only converted from a liquid to a vapor. When benzine or any volatile liquid is evaporated, the same thing is true. But when an oil is changed by oxidation the molecules are broken up and it is changed chemically as well as physically. Even the baking of enamel is both a physical and a chemical process because practically all enamels are made of products containing some linseed oil; while some enamels have little or no oil in them, the ordinary enamel is different from paint or varnish only in the respect that it must be heated to higher temperatures, and therefore we bake it at from 350 to 450 deg., the term "bake" probably being applied because of the excessive temperatures used. In the baking period there is a burn-off, so called because the volatile fumes are visible, followed by an oxidation corresponding to the oxidation that takes place in paint or varnish. There are certain low-temperature enamels having a high percentage of oil that will react exactly like paint or varnish and dry more satisfactorily in humidified air, but I am unable to say whether the same condition holds good for enamels or Japans which are burned off and baked at high temperatures. I presume that the most important need for high-temperature enamel is the production of a surface of enough elasticity to stand up under the usage that hoods and fenders get.

J. A. WILLIAMS:—If the practical painters present

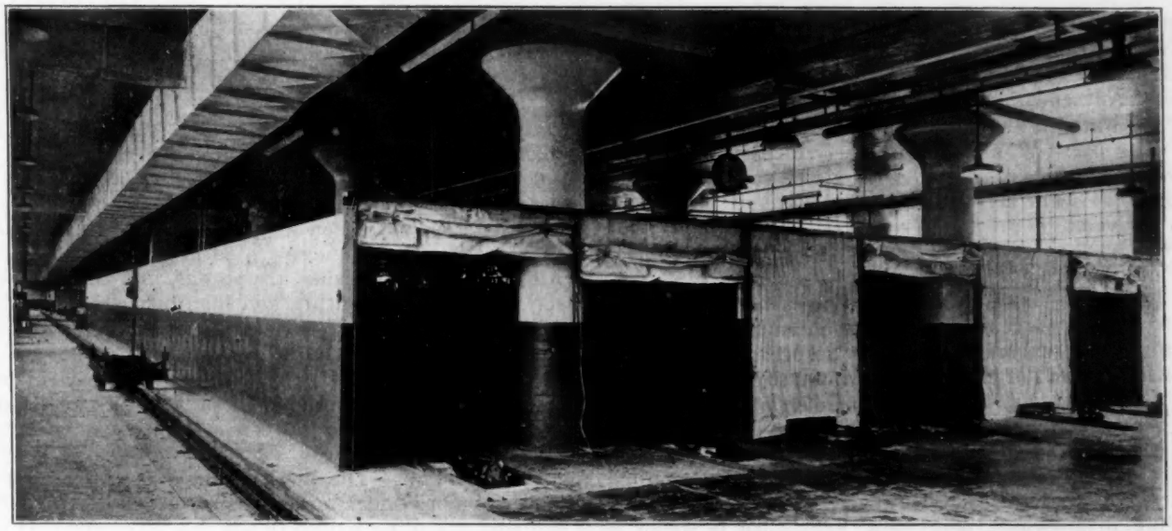


FIG. 12—ANOTHER CHASSIS DRYROOM EQUIPPED WITH A MECHANICAL CONVEYING SYSTEM
In This Plant the Trucks on Which the Chassis Are Carried Through the Dryroom Are Returned when Empty by the Conveyor at the Left of the Illustration

would express themselves, their testimony probably would be contrary to the impression created that it is impossible to produce a painted job correctly unless an artificial drying system is used.

MR. LIPPERT:—I said that it would be possible to dry and oxidize paint and varnish properly under ordinary air conditions if one had the space and time to do this, but modern production requires methods other than air drying. Although air-drying may be satisfactory with a small production and plenty of room, one cannot afford to depend on the weather when producing 200 jobs per day. Is it not true that on certain days a varnish may dry in ordinary air in 24 hr. and that the next day it may require 30 hr.?

MR. WILLIAMS:—I understand that the drying equipment described is good for handling quantity production as required at present, because it forces the drying of varnish regardless of the quality, but there are painters here who know that varnish can be dried successfully without the aid of artificial apparatus. On the seaboard the salt air will go through the artificial drying apparatus.

MR. LIPPERT:—That may be true. We do not dispute the fact that varnish can be air-dried; we are merely trying to establish a uniform condition for drying without forcing the varnish. We predetermine a condition under which a certain varnish will dry most successfully; then we create and control that condition. That is not forcing the varnish. With the proper temperature and humidity one can dry paint or varnish and guarantee a more durable and a better looking finish, whether the drying is done in salt air or not.

As to salt air, I am not sure that there is actually any salt in the air; when moisture is picked up by air in the

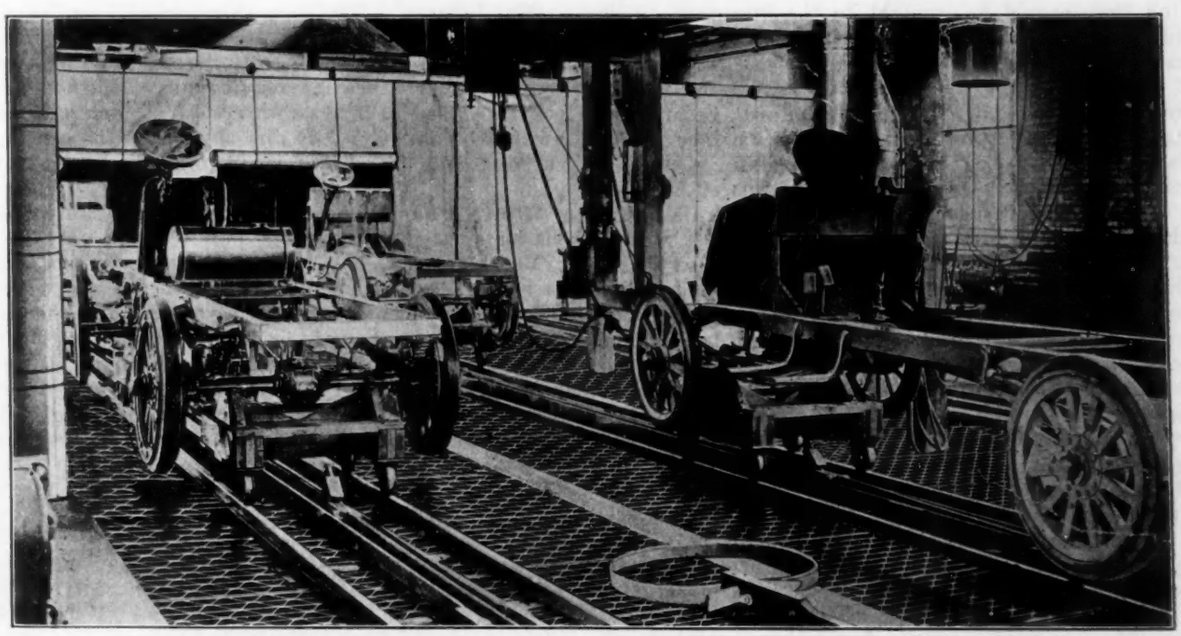


FIG. 13—DRYROOM IN A MOTOR-TRUCK PLANT EQUIPPED WITH A CABLE-TYPE CONVEYOR

form of water vapor it does not carry the salt with it. Moisture is absorbed by the air through an evaporation process and the moisture in the air is really distilled water. Any chemist will agree that the first requisite of distilled water is that it must not contain chlorine.

A MEMBER:—What is the property of paint that makes it suitable for ocean work? During the war many of the trucks that were sent abroad were bare of paint when they arrived.

MR. LIPPERT:—I do not know. Ocean air may have a corroding action.

A MEMBER:—Is that caused by the salt in the air?

MR. LIPPERT:—It may be due to entrained moisture in the air. Our experience in this respect is limited because 90 per cent of the production of automotive vehicles is in plants located on fresh water lakes. The number of cars that are turned out on the Atlantic and on the Pacific coasts is small and the producers are small firms, most of them buying their bodies from some body builder not located on the coast. However, one important body-building firm located near New York City is using an artificial drying system and would not be without it. The system works properly and no difference has been noticed in the finish. As a matter of fact, it ought to make very little difference whether a varnish is air or artificially dried; provided that it is completely dry, the resulting coat is the same in either case. However, we are not interested in the effect of ocean air on the varnish in the can or on the apparatus by which it is dried, but rather in its effect on the dry coating and, if ocean air affects an artificially dried coating, it will undoubtedly have the same effect on an air-dried one. Another consideration that favors artificial drying is that present-day varnishes are made primarily for this purpose and not for air-drying. Six years ago a varnish that could be air-dried in 96 hr. could be dried artificially in 12 hr. Today, there are ordinary 12-hr. varnishes that can be dried artificially in 3 hr. or less.

K. B. BRITTON:—One firm that is using artificial drying equipment has had a number of complaints that the varnish on cars used along the seacoast lost its luster.

MR. LIPPERT:—If such complaints are due to improper drying they should be brought to the attention of the builder of the apparatus. What kind of varnish is most suitable for seacoast work?

E. T. BIRDSALL:—The paint and varnish business is extremely complicated. It probably affords greater opportunity for substitutes than any other business, aside from the oil and grease business. In making paints and varnishes in the days when nothing but linseed oil, gum and turpentine were used, good paint and varnish were produced and a slow-drying varnish gave the best results. Then oxide of lead was used and it hastened the oxidation of the oils. At present there are all kinds of gums; some come from China. There are also all sorts of oils. The Standard Oil Company produces a fine line of driers. One can get any kind of gum or any oil desired except linseed oil, at any price. It is known that if one wants to make a cheap varnish, resin is put into it. Laundry soap is one-third resin. I know of one factory that fired its boilers every year with the staves of resin barrels. Regarding gums, everybody has been trying to use resin. If a varnish is made with resin it will crack; it will crack also if gum and wood oils are used. Chemists have been studying the paint business for the past 7 or 8 years and found that resin can be used. Resin does not make good varnish; nor do wood oils, yet one can make a varnish or a paint with them. It was found that a mixture of resin and wood oil and a peculiar form of lead made as good a varnish as when linseed oil was used; in salt air, for example, the cheap varnish actually stood up better. The drying of an enamel is a distillation and the drying of paint is an oxidation process, although Mr. Lippert calls it "burn-off." Enough binder is left at 400 deg. to make a coating that will stand up. There is just as much substitution in the enamel business as in the paint business. One cannot judge quality until a car has been used a year. I see no reason why the finish coating should not be as good from the accelerated as from a slow process. All paints and varnishes are porous, and there is no reason why the temperature and humidity used in artificial drying should not act to the full depth of the paint and varnish coatings on the bodies.

A MEMBER:—An experienced paint and varnish man claims that he has obtained the best results in the spring and fall for a period of years. How can that be accounted for?

MR. LIPPERT:—The most suitable month of the year for air-drying under normal temperature is April. There is a corresponding month in the fall, although it is not as good as April. There is steam heat in the paint-shop in April and that provides a better condition than at any other season of the year. The Weather Bureau's records show that the humidity is at its lowest percentage in January and at its highest in July, varying from 1 to 6 gr. of moisture per cu. ft. of air. That statement of weather conditions shows that it is possible to obtain for the accelerated drying a condition that will do anything that the air-drying method will do. We know that air-drying is possible if sufficient time is available. We only claim that drying can be done successfully and properly in less time, without deterioration of the product, by the artificial process.

MR. MCGEORGE:—If we do not know the process of so-called drying we cannot make improvements. What is the reaction? It may be called burning or drying or chemical action. It cannot be burning. It may be burning in the sense of oxidation, but oxidation is a distinct chemical change. Drying is simply an evaporation of the moisture and that is not the action we are discussing. What is the change that occurs?

MR. LIPPERT:—The term "drying" as applied to varnish is a misnomer. The process is an evaporation and an oxidation. In drying oils the oil molecules are attacked, some of them are carried away and the residue is converted into a solid substance. The molecules carried away are combined with the oxygen of the air to form carbon dioxide and water. The residue is an oxidized gum.

A MEMBER:—Is the residue that is left detrimental to the luster of the varnish?

MR. LIPPERT:—The residue becomes the body of the varnish. The carbon dioxide that is formed when oxidation takes place is carried away by the air; that is why it is necessary to have sufficient air circulation to carry it away. We have found that if a room having steam-coils is closed up tight and the vapors are not carried away, a blanket is formed that gradually fills the room and surrounds the objects being dried, retarding the process. In other words, when the process of drying in a tightly closed dryroom is started, after all the oxygen in the air has been exhausted and it has been replaced by carbon dioxide, there is nothing left to work with. As a matter of fact, this does spoil the luster; we had examples of that in former days. That is what led to a type of dryroom that has an active air-circulation. Today, we are using anywhere from a 2-min, to a 6-min. air-change to carry away any detrimental gases that might accumulate.

A MEMBER:—Then wherein lies the consistency of reintroducing the air to the blower?

MR. LIPPERT:—The life of the air is renewed in the air-washer. When air in the quantities delivered by the kind of drying equipment under discussion has passed over the body it is not necessarily exhausted. It can be put through the air-washer with safety and its humidity and freshness built up, particularly if an equal volume of fresh air is introduced at the same time. It may not be entirely consistent to use the air again but, since this does no harm and saves operating expense, it would be foolish to do otherwise. In the old type of drying it was customary to close the room tight, use the air it contained until it was all worked out and then throw it away. We recirculate a portion of the air before it is devitalized. We use as much as is compatible with perfect safety. A certain amount of oxygen is required to perform the oxidation and, if sufficient time is allowed, the results are satisfactory. The principal motive today is to produce as much within as little space as possible. If it is a fact that such results as I have indicated can be produced in one-tenth of the time in which they were produced formerly, without ruining the product, is it not better to provide the equipment that will establish such a condition and thus guard against the uncertainty of normal air-drying?

FUEL RESEARCH DEVELOPMENTS

(*Concluded from page* 296)

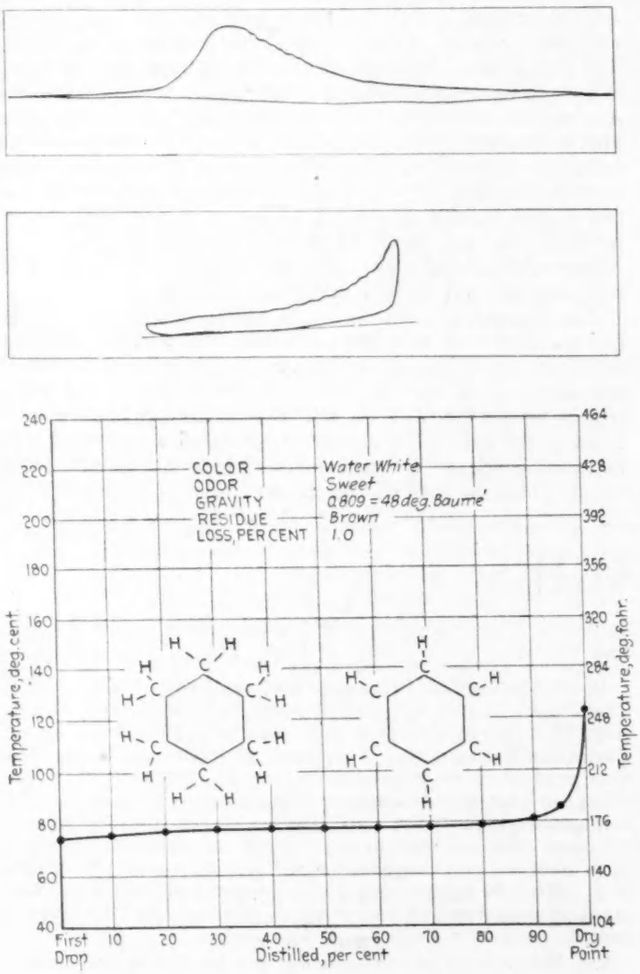


FIG. 14—FUEL STUDY OF A MIXTURE COMPOSED OF 80 PER CENT CYCLOHEXANE AND 20 PER CENT BENZOL

work to overcome the attendant difficulties. When we break a crankshaft, we take it to the chemical laboratory, have it analyzed, see whether the chemical composition is right and then trace the heat-treating. We should apply the same study and method to the fuel theory that we have applied to the heat-treating theory.

The indicator cards produced by the different fuels are shown in Figs. 7 to 15. Fig. 7 shows the distillation curve of a fuel as determined by the standard method given by the Bureau of Mines. The distillation curve shows the temperature at which a fuel evaporates. It is a function of the size of the molecule and is only an easy

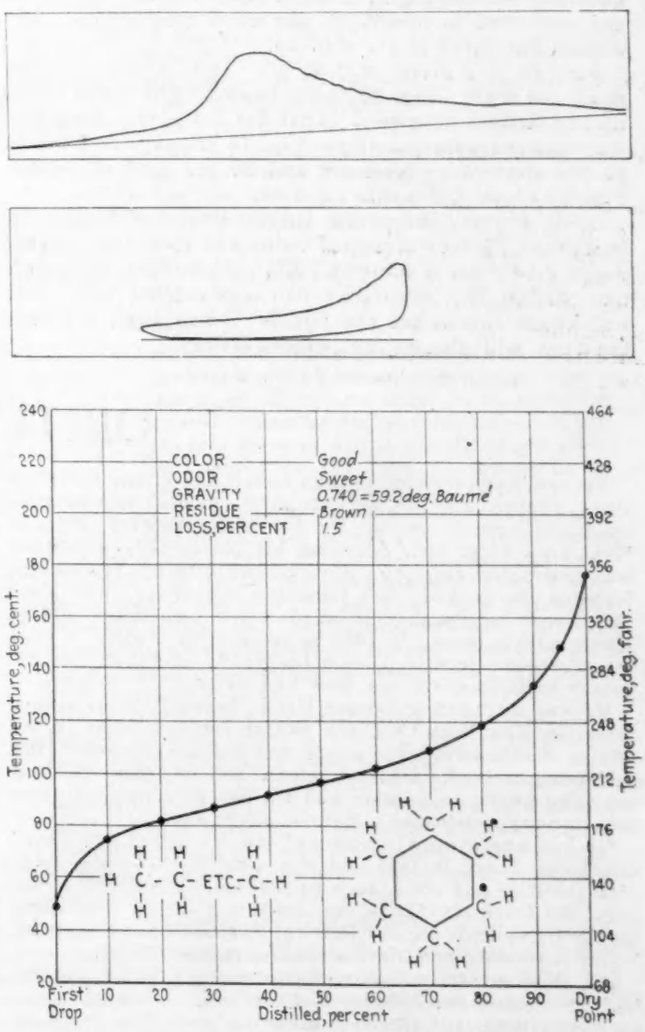


FIG. 15—FUEL STUDY OF A GASOLINE OBTAINED FROM A CALIFORNIA CRUDE OIL

way of weighing the molecule. Fig. 7 shows also the pressure-time and pressure-volume indicator cards produced by commercial denatured alcohol. When the alcohol goes off with a very little increase in temperature, it simply means that all of the alcohol molecules are of about the same size. We know that when water reaches 212 deg. fahr. it all goes off without an increase in temperature. That is simply a proof of the fact that the molecules are the same size. The upper card shows the type of curve produced when alcohol burns. The lower card shows the pressure-volume curve.

Fig. 8 is a fuel study of sulphuric ether. It is shown to demonstrate that volatility has nothing whatever to do with knocking. It is a very volatile fluid and a beautiful knocker. It has a very low vapor-point, and this shows that specific gravity has nothing to do with the knock.

Fig. 9 is a study of butyl alcohol. It does not have so good a distillation curve as sulphuric ether, but has the same general explosion and gives no detonation.

Fig. 10 shows a carbon bisulphide study. It exhibits very bad preignition, so that the pressure-volume loop, where it comes back on itself practically, can be seen; yet it produces absolutely no knock.

Fig. 11 shows kerosene, at the left, and commercial gasoline, at the right, from Pennsylvania crude. We can see what is meant by abnormal combustion. The distillation curve starts way up.

Fig. 12 is a study of fuel oil. It is a little farther down the scale. Fig. 13 shows benzol. The curve comes up and flattens off nicely. That flat top is the thing that we must get with gasoline. Fig. 14 shows a mixture of 80 per cent of cyclohexane and 20 per cent of benzol. Fig. 15 shows California gasoline.

Table 1 gives the excess energy liberated during detonation. We took a cubical content of fuel mixture that would give ether a value of 1000, paraffin 860, olefin 805, naphthaline 780, aromatics 545 and alcohol 620. The anti-knock substances are simply things that, put into the fuel, will absorb that excess energy.

TABLE 1—ENERGY LIBERATED DURING DETONATION

Fuels	Excess Energy Liberated During Detonation
Ethers	1,000
Paraffins	860
Olefins	805
Naphthines	780
Aromatics	545
Alcohols	620

Future Objectives

I hope to interest automotive engineers enough in knowing that there is a road by which physical chemistry, thermo-chemistry and the simple laws of elementary physics can help take this apparently complex combustion problem and analyze it so that we can understand what happens and work better with the people who are producing our fuels to find out whether they can better adapt or better fit them to the machines in which they are to be used. That is the viewpoint that automotive engineers should have. These matters are important. The fuel economy of our motor vehicles must be improved. We must burn less fuel per car-mile. We must reduce the mechanical friction. If we should use measuring apparatus, we might find that it takes more power to turn the engine than it does to run the automobile. The engine frictions are excessive. Engine friction today is one of the biggest problems we have; it can do much to prevent the attaining of adequate fuel economy. A better understanding of fuel combustion will help us to build better and more economical engines.

The Bureau of Standards is doing much good work. Let us utilize all this and take advantage of the Society meetings as occasions to report progress and assemble our data. It is only by reporting on progress and talking matters over that we will attain the desired results. Each year we find we have progressed somewhat. In any new problem the increment of progress is relatively small. That is true of the growth of any business.

OBITUARIES

Peter Cooper Hewitt, noted scientist and inventor, died at Paris, France, Aug. 25, 1921, from pneumonia, following an operation, aged 60 years. He was born, March 5, 1861, at New York City, and, following his preliminary education, was graduated from the Stevens Institute of Technology, Hoboken, N. J., and from Columbia University, New York City, receiving the degrees of Mechanical Engineer and of Electrical Engineer. In 1903 he received the degree of Doctor of Science from Columbia University and a similar degree from Rutgers College, New Brunswick, N. J., in 1916.

He was a trustee of Cooper Union, founded by his grandfather in New York City, and had an active interest in the affairs of industrial corporations and technical societies. His achievements in the fields of science and invention received extensive public recognition and his untimely removal from such activity constitutes a distinct public loss.

He was appointed a member of the United States Naval Consulting Board in 1915 and was a member of many technical societies and clubs, such as the American Physical Society, the Inventors' Guild, the Institute of Radio Engineers, the American Institute of Electrical Engineers, the Society of Naval Architects and Marine Engineers, and others.

His chief inventions included the mercury vapor electric lamp, the static converter or rectifier used to convert alternating electrical currents into direct currents, the electrical interrupter, the wireless receiver, the telephone relay and electric wave amplifier, and wireless telephone and telegraph apparatus. He was elected to Member grade in the Society, Oct. 18, 1916.

H. P. MacDonald, vice-president of Snead & Co., Jersey City, N. J., died at his summer home in New London, Conn., Aug. 25, 1921, aged 41 years. He was born, May 19, 1880, at Louisville, Ky., and was a resident of Montclair, N. J. He was graduated from the Massachusetts Institute of Technology in 1901 with the degree of Bachelor of Science in Civil Engineering and entered the employ of the Snead company the same year, serving successively as assistant superintendent, general superintendent, chief engineer and vice-president. He held membership in the American Society of Mechanical Engineers, the American Society of Civil Engineers and the American Heat-Treating Society.

Mr. MacDonald was responsible for a number of inventions among which was a series relative to the electrical heat-treating of ferrous and non-ferrous metals through a utilization of internal resistance. This system was used extensively during the war for the heat-treating of steel tubing required in American, English and Italian airplane plants and was described in a paper at the 1919 Summer Meeting. He made also a series of inventions useful in the automotive industry and relating particularly to propeller shafts having flexible fabric joints, as well as in regard to the preheating of gasoline through the use of an electric current. He was elected to Member grade in the Society, March 8, 1919.

Current Standardization Work

AT the September Division meetings several recommendations were approved for submission to the Standards Committee members at the January meeting. The recommendations are not published in their entirety in this issue, as the December issue of THE JOURNAL will contain the complete reports of the Divisions to the Standards Committee. Copies of the recommendations are available, however, and will be sent to Society members upon request.

DIVISION MEETINGS

A joint meeting of the Steel Roller Chain Committee of the American Society of Mechanical Engineers, the Committee on Sprockets of the American Gear Manufacturers Association and the Chain Division of the Society's Standards Committee was convened in New York City on Oct. 4, the report of a special committee that met on Oct. 3 being presented for consideration. Definite action was taken on sprocket dimensions. The members of the Ball and Roller Bearings Division met on Oct. 11, members of the Subdivisions on Roller Bearings and Thrust Ball-Bearings also attending the meeting. Determinations were made in the matter of shaft and housing fits and tolerances for ball bearings and annular ball bearing tolerances. Other subjects considered were annular ball bearings of the wide type, roller bearings and thrust ball-bearings. The Electrical Equipment Division met in New York City on Oct. 17 in the Engineering Societies Building. Reports were submitted on flexible conduit, spark-plug hoods, generator and starting-motor mountings, magneto mountings, ignition timer-distributor mountings and magnet wire.

Meetings of the Iron and Steel, Lighting, Parts and Fittings, Frames, Axle and Wheels, Passenger Car and Screw-Threads Divisions have been scheduled, as several Subdivision reports are awaiting final Division action.

AUTOMOBILE BUMPER MOUNTINGS

At the September meeting of the Parts and Fittings Division a Subdivision report was submitted by F. G. Whittington and E. W. Weaver outlining the reasons for standardizing bumpers, possible methods and conditions. The report follows:

Standardization should be undertaken because

(1) The general need for bumpers is conceded and the demand is increasing owing to insurance companies granting discounts for bumper equipment in issuing collision insurance and to the general desire of the public to add to the appearance of passenger cars

(2) Passenger-car factories are beginning to meet the demand for bumpers, showing that they feel the necessity for such equipment, although the majority of bumpers are mounted by owners

(3) At present the passenger-car builders in general are not providing for accommodating a bumper and as a result means are necessary to permit mounting

(4) The majority of mountings are very unsatisfactory as to both safety and appearance

(5) Standardization can easily be worked out by having close cooperation between passenger-car and bumper manufacturers

Bumpers might be mounted

(1) By bolting directly to the vertical web of the frame channel. This method is not covered by patents

(2) By attaching directly to some special means provided by the passenger-car builder

Of these two methods the first is undoubtedly the better. In using this method, cooperation should be obtained from not only the passenger-car manufacturers but from manufacturers of rebound shock-absorbers as it may be possible to use the rear holding bolt of the bumper bracket for shock-absorbers of this type.

Many manufacturers now provide holes for shock-absorbers, whether or not these are factory equipped. It may be necessary, however, to consider a change in the position of the hole for this type of shock-absorber to accommodate the rear hole of the bumper arm.

Some reasons for favoring the bolted-on type of mounting bumpers are that it

(1) Avoids an unsightly looking fitting required on other types of mounting

(2) Is more rigid than any other type of mounting

(3) Is easier to install

(4) Is less subject to loosening if the bumper receives a severe impact

(5) Avoids infringement of patents

(6) Is the cheapest installation

A hole of 17/32-in. diameter located in the usual position of the first frame-horn rivet would be the logical position for the forward hole in the bumper mounting for the following reasons:

(1) The bumper support should be as near the front of the frame-horn as possible to insure rigidity

(2) A distance of $3\frac{3}{8} \pm \frac{5}{8}$ in. from the first rivet hole of the frame-horn to the spring shackle-bolt is used in 90 per cent of the passenger cars now on the market. On the other 10 per cent a hole could be provided at this distance from the spring shackle-bolt without weakening the frame or interfering with the design

(3) The use of a bolt with a flat head instead of a rivet would not be objectionable in case passenger cars were not equipped with bumpers at the factory and it would make an easy attaching means for the first bolt at least

(4) The height of the first rivet in present practice varies from 17 in. to 22 in. from the ground, with the large majority close to $19\frac{1}{2}$ in. Practically all present-day bumper mountings place the bumper about 20 in. above the ground. Considering the thousands of bumpers now mounted and in use the height could be specified as $19\frac{1}{2} \pm 2\frac{1}{2}$ in. measuring to the center of the bumper

Standardization should not limit the maximum width of the impact surface, but should restrict the minimum to 2 in. These figures relate to front bumpers only.

Considering rear bumpers, it is possible to locate rails 23 in. from the ground, but no lower, with a standard mounting applicable to all passenger cars. A wide impact surface would, however, prevent telescoping even at this height. A loaded car would bring this figure down to possibly 21 in.

A bolted-on type of mounting would require an extra hole in addition to the bolt at the first rivet hole as there would be no shock-absorber holes.

Passenger cars having cantilever, full-elliptic or platform springs should have two holes at the extreme end of the frame about 4 in. apart for the mounting of bumper brackets, of which there will always be special models on account of the wide differences in passenger-car design.

BODY NOMENCLATURE

The report of the Subdivision on body nomenclature which was published in the September issue of THE JOURNAL was reviewed at the meeting of the Passenger-Car Body Division held on Sept. 23 and several suggestions that had been received in reference to the report were acted upon. It was felt that there will always be certain special types of custom-

built body differing somewhat from the types covered by the nomenclature proposed, but that such types can be suitably denoted by prefixing the standard names. It was decided to omit the term "town car" as a separate type of body, with the understanding that the word "town" as a prefix should apply to the name of any closed-type body the permanent roof of which does not extend over the driver's seat.

The revised report covers definitions for roadster, touring, sedan, berline, limousine, brougham, sedan-landaulet, berline-landaulet, coupe-landaulet, limousine-landaulet and brougham-landaulet. The complete definitions will be published in the report of the Passenger-Car Body Division in the December issue of THE JOURNAL, together with illustrations for each type.

BOLT AND RIVET SPECIFICATIONS

Information covering average dimensions of bolt and rivet heads, obtained by the Bolt, Nut and Rivet Institute, has been submitted to the Standards Committee and will be acted upon at the next meeting of the Screw-Threads Division. The economic value of standardizing bolts and rivets is obvious, but will be realized only through general adoption of standards approved. This means that the standards finally approved by the Society must be in accord with the best engineering practice. Comments and suggestions have been solicited from automotive users and the action to be taken by the Screw-Threads Division will be guided largely by advices received.

CLUTCH-BEARING OILER

The suggestion that clutch-bearing oilers should be standardized was discussed at the September meeting of the Transmission Division. Although it was recognized that it is difficult to formulate a standard which would be widely used, owing to the fact that this mechanism depends largely upon individual design, A. A. Gloetzner was appointed a Subdivision of one to investigate the subject.

CLUTCH FACINGS

At the meeting of the Transmission Division members held on Sept. 21 the Subdivision report on clutch facings published in the October issue of THE JOURNAL was reviewed. Eighteen sizes of clutch facing for multiple-disc clutches were recommended for adoption and six sizes for single-plate clutches. The final report of the Division will be published in the December issue of THE JOURNAL. It was suggested that the location of the rivets and the rivet sizes should be standardized as this would be of value to clutch and clutch-facing manufacturers and distributers in replacement work. Mr. Bryan, who formulated the original report, was asked to give further consideration to these suggestions and, if feasible, to formulate recommendations.

CIRCULAR SHIMS

The Parts and Fittings Division has recommended that the subject of standardizing circular shims should be tabled indefinitely as the sizes, thicknesses and purposes for which shims are used involve practically all fields of design.

DOOR-FIT CLEARANCES

The Passenger-Car Body Division has proposed as S. A. E. Recommended Practice that door-fit clearances for all doors other than those of the flush type shall be in accordance with the tolerances specified in the accompanying table

DOOR-FIT CLEARANCES

Location	Clearances, In.
Hinge Side	1/8 ± 1/32
Lock Side	3/16 + 1/16, — 0
Bottom	1/4 + 1/16, — 0
Top	1/8 ± 1/32
Jamb	3/16 + 1/16, — 0
Bead	3/32 + 1/32, — 0

These clearances are for all types of body and are measured from wood-to-wood or metal-to-metal before painting.

The Division also proposed for adoption as S. A. E. Recommended Practice that door-flange widths shall be 5/16 in. on the hinge-pillar side and ½ in. minimum on the lock-pillar side and on the bottom.

DOOR HANDLES

At the last meeting of the Passenger-Car Body Division the Subdivision report on door-handle squares, published on page 209 of the September issue of THE JOURNAL was approved, with the additional recommendation that a chamfer of 45 deg. be specified for the end of the externally threaded type. There was considerable discussion with reference to the tolerances specified in the Subdivision report, it being argued that they are too close for commercial practice, but it was decided that they should be retained as they are specified by many large users of 5/16-in. cold-drawn key-stock.

DOOR HINGES

A Subdivision of the Passenger-Car Body Division has been appointed to formulate a recommendation for the exposed type of malleable-iron or forged door-hinge. It was suggested that the following dimensions would be satisfactory as recommended practice

SUGGESTED DOOR-HINGE DIMENSIONS

Material	Plate Width, In.	Thickness, In.	Screws
Malleable	1¾	3/16	4 No. 10
Iron or Forged	2	1/4	4 No. 12
Pressed Steel	2	1/8	4 No. 12

The Clearance between plates when the hinge is closed shall be 1/16 in. at the exposed end and taper to 1/8 in. at the concealed end.

It was also thought that hinge-pin diameters, hinge offsets and possibly hinge projections could be standardized.

ENGINE MUFFLERS

At the meeting of the Engine Division on Sept. 20 a progress report on engine mufflers was submitted by F. M. Seig covering nine sizes of muffler. Mr. Seig stated that a survey of present muffler practice indicates that the 24-in. length is used very extensively and that a standard establishing lengths would be valuable to muffler manufacturers.

In discussing the relation of muffler capacity to the back-pressure it was stated that there is no uniformity in practice. It was thought also that there should be some standard for determining a "silence factor" for mufflers when operating at speeds up to 50 or 60 m.p.h., as above such speeds mufflers cease to function. It was said that experience shows that proper exhaust-port and manifold design will eliminate mechanical engine noises which, when transmitted to the muffler, cause irregular exhaust vibrations.

ENGINE NUMBERS

The problem of numbering automobile engines so as to minimize the stealing of automobiles was discussed at the September meeting of the Engine Division. This problem is important from the users' standpoint, and consequently from the builders' standpoint, because insurance companies are willing to make a reduction in theft-insurance premiums of 7½ per cent for a satisfactory means of numbering engines. Several suggestions were discussed, such as inserting an expanding disc in a counterbored hole in the crankcase; casting numbers of an opaque material in the crankcase in such a way that an X-ray photograph of it would show the numbers cast therein; the use of raised numbers; casting a small thin fin on which the number could be stamped on the crankcase so that the fin could be broken off by the dealer and held by the purchaser; and casting on a small thin brass plate with the edges crimped down ⅛ in. and knurled so as to anchor the crimped edges securely in the crankcase.

After considerable discussion it was felt that the most satisfactory method of numbering engines is to stamp script numbers ¼ in. high and 1/32 in. deep between two parallel vertical ribs ¼ in. wide, ⅛ in. high, 3 in. long and 3 in. apart, the surface of the casting between the ribs being left as cast.

In stamping the numbers the same numbers would be stamped at the top and at the bottom of the 3-in. square space. In case of an error being made in stamping the top or bottom numbers, additional numbers would be stamped directly under or above the number, the numbers containing errors being cancelled by stamping a horizontal line through them. In this way two correct unmutilated numbers would appear on each engine.

It was the consensus of opinion of the Division members, after studying the ideas submitted, that this method of numbering is the most practical and effective means of preventing numbers being changed, especially as it requires no additional parts, tools or operations.

Engine Torques

The members of the Engine Division have decided that it is not feasible to standardize engine torques, owing to the fact that differences in mechanical conditions require entirely different cranking torques.

Fan-Belts and Pulleys

The Engine Subdivision on Fan Belts and Pulleys submitted a report at the last Engine Division meeting covering fan diameters, projected blade-widths and pulley widths for flat fan-belts, depths of pulley groove, belt widths, fan diameters and projected blade-widths for vee fan-belts. An included angle of 38 deg. was recommended for vee-belt pulleys.

Flexible Conduit

The Subdivision on Flexible Conduit submitted two reports for consideration, covering non-metallic flexible conduit and metallic flexible conduit for electrical wiring. These were acted upon at the meeting of the Division held on Oct. 17.

Flywheel Housings

At the September meeting of the Engine Division it was brought out that the present clearance space for crankshaft flywheel bolts and nuts specified in the S. A. E. Standard for flywheel housings is not suitable for small engines having two crankshaft bearings and a large crankshaft flange, and that a clearance should be specified for use when United States Standard, instead of S. A. E. Standard, bolts and nuts are used. After an interesting discussion it was felt that a recommendation should be formulated covering clearance spaces in proportion to the size of the housings instead of but one clearance space for all sizes.

Lock-Washers

The Subdivision report on lock-washers submitted by E. W. Hart for the approval of the members of the Parts and Fittings Division, published on page 119 of the August issue of The Journal, was approved at the September meeting with the following changes

(1) ¼ instead of 1¼-in. dimension for *A* for the 1⅛-in. size S. A. E. Standard bolt
(2) Omitting the lock washer for the No. 10 or 3/16-in. S. A. E. Standard bolt
(3) 3/16 x 1/8 instead of 3/16 x 3/32-in. dimensions for the section dimensions of the lock-washer for the 9/16-in. S. A. E. Standard bolt

Oil-Drain Plugs

Careful consideration was given at the Sept. 20 meeting of the Engine Division to the advisability of designing engines with a conveniently located oil-drain to permit emptying the oil from the crankcase as easily as it was poured into it. It was the general opinion that the oil-drain is so dependent upon individual design and relatively unimportant in connection with interchangeability that no definite type should be standardized. It was thought, however, that a recommendation could be made which would indicate that a suitable oil-drain device should be used, having a minimum size hole and located at the lowest part of the oil-pan or lower half of the crankcase.

The Society is to obtain information as to present oil-drain practice in reference to hole size, location, means of operating and suggestions as to how they might be standardized.

Rubber Bushings

When holes are punched in sheet metal for carrying grommets or bushings, particularly when they are made of rubber, it is recommended by the Passenger-Car Body Division that the hole should be necked. In discussing the feasibility and desirability of standardizing bushing dimensions, the members of the Division thought that no great saving would result, as the cost of molds and material involved is low, but it was recommended that the Electrical Equipment Division consider the desirability of establishing standard dimensions in accord with the S. A. E. Standard for insulated cable.

Water-Pipe Flanges

At the Sept. 12 meeting of the Parts and Fittings Division a series of water-pipe flanges was approved for adoption as S. A. E. Recommended Practice. The flange dimensions recommended are in accord with the dimensions recommended by the Radiator Division for radiator-tank outlets and inlets and permit using standard gaskets.

Water-Pumps

As the design of water and oil-pumps varies to a very large extent, owing to special requirements such as capacity and fuel consumption, members of the Engine Division have tabled this subject as not being feasible to standardize. It is thought, however, that certain water and oil-pump parts might be standardized to advantage.

Windshield Side-Arms

It has been thought that the Passenger-Car Body Division should formulate a standard for the shanks of windshield side-arms so that body builders can furnish standard holes in the body frames. This matter was discussed at the last meeting of the Division, when it was suggested that the shank diameter should be in odd number sizes and the hole diameter in even number sizes, and that there should be a definite series of lengths and threaded ends. The Society is to obtain information from windshield manufacturers bearing on present practice.

(Wire Mesh)

At the meeting of the members of the Parts and Fittings Division held in September the standardization of wire mesh was considered feasible. Data will be gathered as to what mesh and corresponding wire sizes are used for oil, air, gasoline and water strainers.

Wiring for Beads

The Passenger-Car Body Division has proposed as S. A. E. Recommended Practice that for engine hoods up to and including 30 in. long top-hinge rods shall be 5/16-in. diameter and side-hinge rods ¼-in. diameter, and that for fenders, aprons and splash-guards the wiring used for beading should be No. 11 Birmingham gage bright basic wire. At the time this recommendation was made it was brought out that many fenders are being made without beadings, but the members of the Division considered that such practice is not in accord with the best engineering construction as it leaves the fender edges sharp.

THE ENGINEERING APPROACH

THE public is apparently beginning to lose faith in shortcuts and political expediency and will more and more demand social and economic readjustments based on a full understanding of all the facts and a thorough-going orientation of all the elements in any given situation. There is clearly discernible a growing sense that somehow the engineering approach is what is needed if ordered progress is to be the watchword for a civilization in the agonizing process of seeking new levels.—M. L. Cooke.

ACTIVITIES OF THE SECTIONS

Sections Calendar

BUFFALO
(Secretary—George H. Pettit, 1569 Jefferson Street, Buffalo)
Nov. 15—Inlet Manifolds by R. W. A. Brewer

CLEVELAND
(Secretary—E. W. Weaver, 5103 Euclid Avenue, Cleveland)

DAYTON
(Secretary—R. B. May, Dayton Engineering Laboratories, Dayton)

DETROIT
(Assistant Secretary—Mrs. B. Brede, 1361 Book Building, Detroit).

INDIANA
(Secretary—B. F. Kelly, Weidely Motors Co., Indianapolis)

METROPOLITAN
(Secretary—F. E. McKone, 347 Madison Avenue, New York City)
Nov. 18—Chassis Lubrication by C. T. Myers

MID-WEST
(Secretary—Taliaferro Milton, 140 South Dearborn Street, Chicago)

MINNEAPOLIS
(Secretary—C. T. Stevens, 13 South Ninth Street, Minneapolis)

NEW ENGLAND
(Secretary—H. E. Morton, B. F. Sturtevant Co., Hyde Park, Boston)
Nov. 11—Ignition Meeting at Springfield

PENNSYLVANIA
(Secretary—T. F. Cullen, Chilton, Co., Market and 49th Streets, Philadelphia)
Nov. 22—Fuel and Diesel Engine Meeting. Speakers—H. L. Horning and A. K. Brumbaugh

WASHINGTON
(Treasurer and Acting Secretary — C. H. Young, 210 Riggs Building, Washington)

THIRTY members of the Mid-West Section met at dinner on Oct. 7. O. B. Zimmerman, chairman of the Section's Paper Committee, reported on the plans for the season's activities. The program will consist of a series of meetings on the fundamental theories of thermodynamics and a study of the laws of heat, a knowledge of which is essential for the designing of internal-combustion engines. Prof. Daniel Roesch addressed the Section members at their meeting held on Oct. 31.

Thomas Midgley, Jr., gave a talk on liquid fuel reserves at the Oct. 13 meeting of the Indiana Section.

The Cleveland Section held its first fall meeting on Oct. 21. The Council of the Society met in Cleveland on the same day and a number of the officers of the Society and members of the Council took advantage of the opportunity to attend the Section meeting in the evening. President Beecroft spoke very interestingly and earnestly on the standardization work of the Society. H. A. Schwartz gave an account of a series of tests on the physical properties of malleable cast iron.

The Detroit Section opened its season on September 30 with an address by Dr. H. C. Dickinson, manager of the Research Department of the Society. An added feature of the program was the showing of moving pictures of the recent aerial bombing operations against battleships. Past-President Coffin gave an address on the necessity of enabling Federal legislation on aircraft regulations.

C. H. Metz presented some automotive historical notes and personal reminiscences at the Oct. 13 session of the New England Section. Prof. William J. Drisko discussed automobile head-lamp illumination and the Massachusetts regulations thereon. At the next meeting of the Section, scheduled for Nov. 11 at Springfield, the subject will be ignition.

The Metropolitan Section will listen to C. T. Myers and others discuss the subject of chassis lubrication at a meeting on Nov. 17. Both approved methods and recent developments will be considered, including self-lubricating substitutes for spring-shackles.

The members of the Pennsylvania Section will add to their knowledge of internal-combustion engine fuel and how to use it, through papers by H. L. Horning and A. K. Brumbaugh which will be given at the Section meeting scheduled for Nov. 22.

The Minneapolis Section reports a rearrangement of the order of presentation of the papers for its coming meetings. It will devote the season to tractor subjects in accordance with the original plan. Meetings are scheduled for the first Wednesday of each month, at the Builders' Exchange.

Robert W. A. Brewer will give a paper on inlet manifolds before the Buffalo Section on Nov. 15.

CALCIUM CHLORIDE FOR ROADS

IF one takes a small amount of calcium chloride and places it on an ash-tray or paper-weight, one will observe the rapidity with which it attracts moisture from the air, each granule turning to a drop of water. This is the effect calcium chloride has upon a road. It has none of the detrimental properties of oil and no effect upon tires or clothing, nor is it tracked from the road onto the sidewalks and into the home. It is readily applied with an ordinary lime or fertilizer sower.

This year the Michigan Highway Commission contracted for 6000 tons, to be used on trunk-line gravel roads. The practice followed is to apply calcium chloride on gravel roads in the spring, just as soon as they have dried out and been graded or scarified. The second application is usually made in August. Satisfactory results, as a rule, can be obtained with two applications, but on very heavily traveled roads three applications may be necessary. The material has an accumulative effect; that is, a road treated one year will not require as heavy an application the second year, unless it has been resurfaced. An 18-ft. gravel road requires about 8 tons per mile for a treatment. The cost is approximately $200 per mile applied, which is about one-half of the cost of oil applied.

Connecticut is a heavy user and the Highway Departments of Wisconsin and Minnesota have become sufficiently interested in calcium chloride to purchase trial cars. The Michigan Highway Department believes calcium chloride to be the greatest road-saver to date, considered from all angles. The road surface is held firmly and compact, thereby reducing the frequency of resurfacing with gravel. Grand Rapids, Mich., has this year purchased and applied 800 tons within the city limits and completely displaced its sprinkling equipment. Ann Arbor, Mich., has done likewise and a great many smaller cities have applied the material to their main streets. It should not be applied to a road that has been treated with oil, unless the road is scarified or resurfaced. This is because oil makes the road waterproof and calcium chloride will not function on a waterproof road. If a road has several inches of dust on it, this must first be scraped off or the application delayed until a rain packs it down.—The Timken.

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Sept. 10 and Oct. 10, 1921. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ASIRE, HORACE W. (M) research engineer, electrical department, General Motors Research Corporation, *Dayton, Ohio.*

BOYNE, WILLIAM KENNEDY (M) Newfield Avenue, R. F. D. 30, *Stamford, Conn.*

BRADLEY, JOHN J., JR. (J) Lincoln Motor Car Co., *Detroit,* (mail) 1404 East Jefferson Avenue.

CALKINS, ADDISON N. (M) superintendent, Electric Wheel Co., *Quincy, Ill.,* (mail) 2334 Maine Street.

CARPENTER, FIRST-LIEUT. CHARLES L. (A) *Fort Crook, Neb.*

CARPENTER, MANSON C. (A) sales engineer, Holley Carbureter Co. *Detroit,* (mail) 323 Tuxedo Avenue, *Highland Park, Mich.*

CLERK, SIR DUGALD (F M) civil engineer, National Gas Engine Co., Ltd., Ashton-under-Lyne, England, (mail) 57-58 Lincoln's Inn Fields, *London, W.C.2.*

COLBURN, HERBERT C. (M) Ajax Mine, *Victor, Col.* (mail) Box 229.

CORSON, BOLTON L. (M) engineer, H. H. Franklin Mfg. Co., *Syracuse, N. Y.,* (mail) University Club.

DOE, THOMAS B. (M) vice-president and general manager, United States Cartridge Co., *Lowell, Mass.*

DORIOT, GEORGES F. (J) Doriot Flandrin Parant, Denis, Courbevoie, Seine, France, (mail) 14 Story Street, *Cambridge, Mass.*

DUFFECK, FRANK W. (A) proprietor, Electric Power Maintenance Co., 1101 Monroe Street, *Toledo.*

ERSKINE, JAMES E. (A) chief engineer, Perfection Engineering Products Corporation, 707 East Bay Street, *Jacksonville, Fla.*

FAGAN, XEN (A) general manager Diamond branch, Rome Wire Co., 56 Clyde Avenue, *Buffalo, N. Y.*

FISCHBECK, HENRY J. (M) foreman of heat-treating department, Wright Aeronautical Corporation, Paterson, N. J., (mail) 137 22nd Street, *Irvington, N. J.*

FITZ GERALD, MAJOR M. L. (A) Maxwell Motor Co. of Canada, Ltd., *Windsor, Ont., Canada.*

FREDERICKS, ELMER VICTOR (A) field manager, Self Seating Valve Co., *Chicago,* (mail) 2021 North Spaulding Avenue.

GEARHART, MAJOR GUY L. (S M) Air Service, McCook Field, *Dayton, Ohio.*

GIBSON, ALLEN W. (A) special representative, Prest-O-Lite Co., Inc., New York City, (mail) 132 23rd Street, *Elmhurst, N. Y.*

GINSBERG, SAMUEL (A) partner, Ginsberg Motor Co., 288 St. Catherine Street, West, *Montreal, Canada.*

HEINES, CHRISTIAN F., SR. (M) president, Big Farmer Corporation, *Fort Madison, Iowa* (mail) 719 Fifth Avenue.

HERON, S. D. (S M) aeronautical mechanical engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio,* (mail) 212 West Monument Avenue.

HOBART, JOHN P., JR. (J) draftsman, Union Gas & Electric Co., *Cincinnati,* (mail) 2419 Salutaris Avenue.

HOOVEN, ALBERT M. (A) secretary and treasurer, Meteor Motors Corporation, Philadelphia, (mail) 25 North Wycombe Avenue, *Lansdowne, Pa.*

INSLEY, ROBERT (J) aeronautical mechanical engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio,* (mail) Powerplant laboratory, McCook Field.

JARROW, HARRY W. (A) Western manager, American Felt Co., 325 South Market Street, *Chicago.*

JOHNSON, FRED V. (M) consulting engineer, Avery Co., *Peoria, Ill.*

JOHNSON, JOHN E. (M) assistant chief draftsman, Reo Motor Car Co., *Lansing, Mich.,* (mail) 1319 West Hillsdale Street.

KERSHAW, LEONARD F. (J) draftsman, Fox Motor Car Co., *Philadelphia,* (mail) 1233 West Hazzard Street.

KING, KENNETH J. (E S) student, University of Wisconsin, *Madison, Wis.* (mail) 927 West Dayton Street.

LAVERY, LORNE F. (J) engineering draftsman, Detroit office, New Departure Mfg. Co., Bristol, Conn., (mail) 1564 Pine Street, *Detroit.*

LEVENE, BERNARD N. (A) vice-president and service manager, Levene Motor Co., *Philadelphia,* (mail) 908 Rockland Street.

LOCKWOOD, F. R. (M) chief engineer, A. J. Detlaff Co., Inc., *Detroit,* (mail) 3766 West Philadelphia Avenue.

LOVE, HORACE (A) H. H. Franklin Mfg. Co., *Syracuse, N. Y.*

MACLEAN, ALLEN D. (J) assistant chief engineer, New Departure Mfg. Co., *Bristol, Conn.,* (mail) 115 Federal Street.

MCGRATH, JOHN (A) assistant treasurer, Eberhardt Mfg. Co., *Cleveland,* (mail) 2131 Adelbert Road.

MCILHINEY, DONALD W. (J) *Great Neck, N. Y.*

MARSHALL, J. F. (A) territory manager of sales, American Felt Co., 1 Greenwood Building, *Cincinnati.*

MARSHALL, LEWIS C. (A) president, Pressure Proof Piston Ring Co., 107 Massachusetts Avenue, *Boston, Mass.*

MAYNARD, H. E. (M) Maxwell Motor Corporation, *Detroit.*

MILLER, EDWARD J. (M) chief draftsman, Allen Motor Co., *Columbus, Ohio,* (mail) 962 Delaware Avenue.

MITCHELL, ALBERT F. (S M) automotive engineer, tank, tractor and trailer division, Ordnance Department, *Washington,* (mail) 2109 F Street, N.W.

MOTTINGER, BYRON T. (M) chief engineer, Quaker City Rubber Co., Philadelphia, (mail) 1123 Harrison Street, *Frankford, Philadelphia.*

PARKER, JESS (A) chief inspector, Jordon Motor Car Co., *Cleveland,* (mail), 1848 Colonade Road, Colonial Heights.

PARSONS, J. B. (M) engineer, storage battery division, Prest-O-Lite Co. of Canada, Ltd., *Toronto, Ont., Canada.*

PIERCE, EDWARD M. (S M) engineering division, Air Service, McCook Field, *Dayton, Ohio,* (mail) 11 Calvert Apartments.

PROSPERI, A. G. (A) sales engineer, Oakland Motor Car Co., *Atlanta, Ga.,* (mail) Apartment A-12, Wyndham Courts.

RICE, JOHN H. (J) mechanical draftsman, American LaFrance Fire Engine Co., Inc., 101 LaFrance Street, *Elmira, N. Y.*

ROBIE, THEODORE M. (M) New York service engineer, Fairbanks, Morse & Co., Chicago, (mail) Box 605, *Oyster Bay, N. Y.*

ROUDENBUSH, ELMER F. (A) truck designer and checker, Stewart Motor Corporation, *Buffalo, N. Y.,* (mail) 38 Northumberland Street.

RUPP, JOHN L. (M) manager of manufacturers sales, Westinghouse Union Battery Co., *Swissvale, Pa.*

SCHEEL, HERBERT (A) president, Scheel Motors Co., St. Louis, (mail) 7449 Gayola Place, *Maplewood, Mo.*

SEBRING, JOSEPH L. (A) assistant manager and director of sales, Miles Piston Ring Co., 5353 South State Street, *Chicago.*

SHIPLEY, MILLARD J. (A) tractor instructor, Michigan State Auto School, 3729 Woodward Avenue, *Detroit.*

SHRUM, A. T. (J) chief draftsman, Walker Vehicle Co., State and 87th Streets, *Chicago.*

SMITH, OSCAR A. (M) superintendent, Coit plant, National Acme Co., *Cleveland.*

SMITH, ROY D. (J) assistant chief engineer, Front Drive Motor Co., *Kansas City, Mo.,* (mail) 3023 Forest Avenue.

STURGIS, HARRY L. (A) assistant superintendent, Locomobile Co., New York City, (mail) 503 West 174th Street.

TAYLOR, LOUIS E. (A) mechanical production department, Brewster & Co., Long Island City, N. Y., (mail) 108 Church Street, *West Haven, Conn.*

WALKER, CLARENCE S. (M) 452 Ellicott Square, *Buffalo, N. Y.*

WAMPLER, HOMER H. (A) owner and manager, Dayton Automotive Specialty Co., 310 East 2nd Street, *Dayton, Ohio.*

WARE, MARSDEN (J) mechanical engineer, National Advisory Committee for Aeronautics, Langley Field, *Hampton, Va.*

WILKINS, HAROLD S. (M) managing engineer, lighting plant division, H. C. Dodge, Inc., Boston, (mail) 98 Central Street, *Somerville, Mass.*

WILSON, ROBERT E. (M) director of research, Research Laboratory of Applied Chemistry, Massachusetts Institute of Technology, *Cambridge* 39, *Mass.*

WOOD, JOHN M. (J) tool designer, Stout Engineering Laboratories, 4434 Seyburn Avenue, *Detroit.*

YAGLOGLOU, C. P. (J) mechanical engineer, American Society of Heating and Ventilating Engineers, Bureau of Mines Experiment Station, *Pittsburgh.*

Applicants *for* Membership

The applications for membership received between Sept. 21 and Oct. 15, 1921, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

BARCLAY, ERIC, sales manager and technical advisor, Teal & Co., Inc., *Manila, P. I.*

BARROW, ARTHUR T., general manager, Nattrass & Harris Motor Co., Ltd., *Wellington, N. Z.*

BOLGIANO, JOHN F., chief draftsman, transportation, balloon and airship section, Air Service, McCook Field, *Dayton, Ohio.*

BOSWERTH, ALVAH H., vice-president and chief designing engineer, Colador Engineering Corporation, *Long Island City, N. Y.*

BURNELL, E., assistant to president, Overman Cushion Tire Co., *New York City.*

CHASE, RUSSELL D., manager, General Motor Repair & Mfg. Co., *Milwaukee.*

CLARKE, LOUIS E., sales manager, bearing and die casting departments, Hoyt Metal Co., Boatmen's Bank Building, *St. Louis.*

COBURN, HAL H., supervisor of shops, Wellesley Public Schools, *Wellesley, Mass.*

CONNORS, WALTER WILLIAM, engineer, 12 Oakwood Place, *Elizabeth, N. J.*

CURTIS, WILLIAM G., master mechanic, House & Meyers, Inc., *Los Angeles, Cal.*

DAYTON, JOHN C., engineer and manager, Wallace and Granite Streets, *Harrisburg, Pa.*

ECKMAN, NORMAN H., vice-president and general manager, Center Fed Spring Insert Sales Co., *Wilkes-Barre, Pa.*

EMERSON, L. A., head of automotive department, Dunwoody Institute, *Minneapolis.*

EVANS, BOB G. N., secretary, Landman-Griffith Co., *Toledo, Ohio.*

FARQUHARSON, F. B., student, University of Washington, *Seattle, Wash.*

FOSTER, ERNEST H., vice-president, Power Specialty Co., *Dongan Hills, Staten Island, N. Y.*

FRASER, WILLIAM R., service manager, Henry W. Peabody & Co., *Buenos Aires, Argentina, South America.*

GUSTAFSON, HUGO H., chief draftsman, Master Truck Co., *Chicago.*

HALDAR, S. N., automotive student, 90 Sibley Street, *Detroit.*

HANOVER, H. T., president and general manager, Apex Motor Corporation, *Ypsilanti, Mich.*

HAYES, HAROLD W., division engineer, Dodge Bros., *Detroit.*

JARDINE, HENRY, service manager, Standard Steel Motor Car Co., *Boston.*

KEIM, BYRON L., consulting engineer, Automotive Parts Co., *Pittsburgh.*

KLINE, CHARLES W., assistant body engineer, Milburn Wagon Co., *Toledo, Ohio.*

KUHNE, GUS A., garageman, Gus A. Kuhne, *Detroit.*

LENNOX, FRANK H., assistant manager and sales manager, Hoover Steel Ball Co., *Ann Arbor, Mich.*

MCGREW, M. L., rail-car department, International Motor Co., 25 Broadway, *New York City.*

MCKNIGHT, CHARLES, JR., works manager, Carbon Steel Co., *Pittsburgh.*

MICHAELS, CHARLES, president, Michaels & Monroe, *New York City.*

MIKI, KICHIHEI, military engineer, Japanese Army, *Tokyo, Japan.*

MILLER, HOWARD A., junior partner, Automotive Service Co., *Rochester, N. Y.*

NEELANS, HAROLD G., student, University of Michigan, *Ann Arbor, Mich.*

O'CONNOR, THOMAS A., service manager, Western Motors Co., *Los Angeles, Cal.*

PACKER, A. HERBERT, instructor, ignition department, Ambu Institute, 2632 Prairie Avenue, *Chicago.*

PATTERSON, C. E., works manager, Athey Tractor Co., 5631 West 65th Street, *Chicago.*

PEAVEY, CLARENCE W., instructor technical and practical automobile repair, Main Avenue High School, *San Antonio, Tex.*

RAWLINS, EDWARD B., draftsman, C. & G. Cooper Co., *Mt. Vernon, Ohio.*

RUTAN, HARVEY JOSEPH, draftsman and designer, Stromberg Motor Devices, *Chicago.*

SHAW, STILLMAN, consulting engineer, 60 Prospect Street, *Hartford, Conn.*

SOCIETE ANONYME ADOLPHE SAURER, *Arbon, Switzerland.*

THUM, WILLIAM CLARK, student, 2441 Haste Street, *Berkeley, Cal.*

TILLINGHAST, CAPT. T. E., engineering division, Air Service, McCook Field, *Dayton, Ohio.*

UNDERWOOD, ARTHUR J., student, University of Michigan, *Ann Arbor, Mich.*

VANE, C. A., general counsel, National Automobile Dealers' Association, *St. Louis.*

WORLEY, LEE, chief draftsman, Witteman Aircraft Corporation, *Hasbrouck Heights, N. J.*

WRIGHT, BENJAMIN F., chief draftsman, Wright-Fisher Engineering Co., *Detroit.*